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Volcanology

8699 Volcanology topics
MICROSCALE CHEMICAL EFFECTS OF LOW TEMPERATURE ALTERATION OF DSDP BASALTIC GLASSES
I.B. Allin-Pysik (The PQ Corporation, P.O. Box 258, Lafayette Hill, PA 19403) and S.E. Sommer
Major and trace element compositions of fresh and altered glasses from DSDP Site 396B were determined using the electron microprobe and a selected area x-ray fluorescence technique. The glasses were found to release approximately one-half of the original Si and Al, two-thirds of the Mg and Na and over 90% of the Ca originally present, during alteration to palagonite. Fe and Ti were found to be immobile, and K was increased 40-fold by concentration from seawater. For the trace metals, over one-quarter of the Zn, Cu and Ni were released, 40% of the Mn, and over 10% of the Cr. These changes apply only to the conversion of fresh glass (sideromelane) to palagonite (smectite), and do not include the effects of authigenic phillipsite and calcite reprecipitated locally. Differences between the effects of low temperature weathering on the crystalline basalts and the glasses appear to be primarily a function of the susceptibility of the primary mineral phases to attack, with the glass, as the least stable phase, most altered. (Alteration, glass, palagonite, smectite.)
J. Geophys. Res., Red, Paper 1B1047

8699 Volcanology topics
SEISMICITY OF MOUNT HOOD AND STRUCTURE AS DETERMINED FROM TELESEISMIC P-WAVE DELAY STUDIES
C. S. Weaver (U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025) S. M. Green and H. M. Iyer
A 16-station seismic network was established in the Mount Hood area of Oregon in 1977 as part of a multidisciplinary study to evaluate the geothermal potential of a typical Cascade volcano. The immediate objective was to monitor local seismicity and to study the P-wave velocity structure of the crust and upper mantle. During the 13 months the network was in operation, 10 local earthquakes were recorded. All these events are spatially associated with the volcano and occurred at shallow depths roughly defining a zone striking north-northwest. The largest earthquake, a magnitude 3.4 event, was preceded by a single foreshock and followed by three locatable aftershocks. These and the five other located earthquakes were of magnitude less than 2.0. Fifty-five teleseisms were recorded by the network and used in a teleseismic P-wave delay study. The residuals from the P-delay study indicate that there is no significant velocity anomaly associated with the Mount Hood volcano and only small velocity variations in the Mount Hood region.
J. Geophys. Res., Red, Paper 1B1016

8699 Volcanology topics
PLEISTOCENE HIGH-SILICA RHYOLITES OF THE COSO VOLCANIC FIELD, INYO COUNTY, CALIFORNIA
C. R. Bacon (U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, California 94025), R. Macdonald, R. L. Smith, and P. A. Baedecker
The high-silica rhyolite domes and lava flows of the bimodal Pleistocene part of the Coso volcanic field provide an example of the early stages of evolution of a silicic magmatic system of substantial size and longevity. The rhyolites are sparsely porphyritic to virtually aphyric, containing qz + pl + san + bi + hb + mt ± allanite ± opx ± cpx ± fa ± il ± ap ± zircon phenocrysts. Major- and trace-element compositions of all 38 rhyolite extrusions are consistent with derivation from somewhat less silicic parental material by liquid-state differentiation processes in compositionally and thermally zoned magmatic systems. Seven chemically homogeneous eruptive groups emplaced approximately 1.0, 0.6, 0.24, 0.17, 0.16(?), 0.09, and 0.06 m.y. ago can be distinguished on the basis of trace-element and K-Ar data. The oldest two groups are volumetrically minor and geochemically distinct from the younger groups, all five of which appear to have evolved from the same magmatic system. Erupted volume-time relations suggest that small amounts of magma were bled from the top of a silicic reservoir at a nearly constant long-term rate over the last 0.24 m.y. The interval of repose between eruptions appears to be proportional to the volume of the preceding eruptive group. This relation suggests that eruptions take place when some parameter, which increases at a constant rate, reaches a critical value; this parameter may be extensional strain accumulated in roof rocks. Extension of the lithosphere favors intrusion of basalt into the crust, attendant partial melting, and maintenance of a long-lived silicic magmatic system. Consideration of the mass of magma that must have been intruded into the crust in order to explain the anomalously high heat flow near the center of the rhyolite field and comparison of age, volume, mineralogic, and compositional characteristics of the rhyolites with those of caldera-forming systems suggest that the Coso silicic system may contain a few hundred km^3 of magma. The Coso magmatic system may eventually have the potential for producing voluminous pyroclastic eruptions if the safety valve provided by rapid crustal extension becomes inadequate to (1) defuse the system through episodic removal of volatile-rich magma from its top and (2) prohibit migration of the reservoir to a shallow crustal level.
J. Geophys. Res., Red, Paper 1B0907

8699 Volcanology topics
CALDERAS IN THE PRECAMBRIAN TERRANE OF THE ST. FRANCOIS MOUNTAINS, SOUTHEASTERN MISSOURI
J. R. Sides (Department of Geology, University of Texas at Arlington, Arlington, Texas 76019) M. E. Bickford, E. D. Shuster, and R. L. Nusbaum
Precambrian igneous rocks in the St. Francois Mountains, southeastern Missouri consist of silicic volcanic rocks, mostly ash-flow tuff, and epizonal granitic plutons. The distribution of these rocks suggests that the western and northeastern part of the area, which is underlain mostly by plutons, is a deeper part of the crust than that underlain mostly by volcanic rocks. In the eastern St. Francois Mountains the occurrence of a thick rhyolitic ash-flow tuff and its distribution relative to a large, high-silica granite pluton suggest that the ash-flow is the principal eruptive material of a caldera and that the granite body is the frozen magma chamber that was below it. Low-silica plutons peripheral to the larger granite body are interpreted as ring plutons. A zone of angular unconformity with accompanying chaotic structure and megabreccia indicates that a second caldera formed to the west. The occurrence of the thick Taum Sauk Rhyolite in the western St. Francois Mountains may indicate that yet another caldera formed in this part of the terrane.
J. Geophys. Res., Red, Paper 1B0892

8699 Volcanology topics
ATTENUATION OF P AND S WAVES IN A MAGMA CHAMBER IN LONG VALLEY CALDERA, CALIFORNIA
Floriana Ryall and Alan Ryall (Seismological Laboratory, University of Nevada, Reno, NV 89557)
Shallow earthquakes around the southwest boundary of Long Valley caldera, west of the Hilton Creek fault, are characterized by lack of S-waves at regional seismic network stations to the northwest, north and northeast, and P-waves for these same station-event combinations are deficient in frequencies higher than about 2-3 Hz. Earthquakes east of the Hilton Creek fault and southeast of the caldera have normal P- and S-wave signatures at the same stations. These effects are explained by propagation through a magma chamber in the south-central part of Long Valley caldera, at depth greater than 7-8 km.
Geophys. Res. Lett., Paper 1L0812

8699 Volcanology topics
MAGMATIC VOLATILES IN EXPLOSIVE RHYOLITIC ERUPTIONS
J. C. Eichelberger (Sandia National Laboratories, Albuquerque, NM 87185) and H. R. Westrich
Obsidian clasts in rhyolitic tephra deposits preserve preeruption magmatic volatile contents, providing a direct means for determining the volatile content of explosively erupted magmas. Small to moderate volume Plinian eruptions (10^{-3} to 10^{-1} km) appear to be driven by 0.5-1.0 wt.% volatiles, consisting dominantly of H_2O with minor CO_2. Analysis of obsidian from eruptive sequences consisting of tephra and flows indicates that this hydrous magma abruptly overlies magma with only 0.1-0.2 wt.% H_2O. (rhyolitic magma, volatiles, explosive volcanism, tephra)
Geophys. Res. Lett., Paper 1L0931

Information Related to Geologic Time

9175 Precambrian
PALEOMAGNETISM OF A KEWEENAWAN AGE INTRUSIVE NEAR CLAM LAKE, WISCONSIN
W. Kean (Department of Geology and Geophysical Sciences, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201) R. Swingen
Two long cores from a magnetite-rich gabbroic intrusion near Clam Lake, Wisconsin were studied to obtain paleopole positions to aid in determining the time of intrusion and learn more about the tectonics of the area. This intrusion was suspected to be late Precambrian in age. A.F. demagnetization above 150 oe. produced reliable remanent directions. The cores were not azimuthally oriented, therefore small circle plots were made for each sample using 12 different horizontal orientations. The best pole position was considered to be where the small circle path crossed the Precambrian polar wander curve. This gave a normal pole at N 30° E 176° which is middle Keweenawan in age. The average inclination and declination for 14 of the 18 pole positions was 35° and 288° respectively, which is consistent with aeromagnetic maps of the area. The 35° inclination is consistent with most middle Keweenawan rocks of the area, after they have been corrected for a 10°-30° tilt. This suggests that the Clam Lake area was not tilted after intrusion. Basalt dikes in the gabbro gave consistently lower inclinations, which suggest a late Keweenawan time for their formation. (Precambrian, Keweenawan, Paleomagnetism)
Geophys. Res. Lett., Paper 1L0613

Symposium on Qinghai-Xizang (Tibet) Plateau—Beijing (Peking), China

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Academia Sinica arranged an historic conference, including a field excursion, on the Qinghai-Xizang (Tibet) plateau. It took place May 25th through June 14, 1980. Some 80 scientists from 18 foreign countries, representing such diverse fields as anthropology, biology, geography, geology, geophysics, high-altitude physiology, and meteorology, were invited to participate in this multidisciplinary international meeting—the first of its kind in the People's Republic of China. They exchanged information and opinions with some 240 Chinese scientists. Although the conference covered a wide range of topics, there was a strong predominance of solid earth sciences (nearly 70% of the papers presented), which is the emphasis of this report.

The Qinghai-Xizang (Tibet) plateau is a unique feature of the surface of the earth because of its very high elevation (averaging nearly 5 km above sea level) and its enormous areal extent (about 2.5 million km^2). Many of the peculiar characteristics of the plateau are a direct consequence of its extensive elevation and its position in the rain shadow of the Himalayan range. Tibet's elevation has long been attributed to a thick crust that was believed to be a result of the collision of the Indian subcontinent with Eurasia [see Figure 13 in *Argand*, 1924]. However, the precise mechanism for the development of the thick crust and the high plateau and its effects on world climate, the distribution of plateau biotas, and human life have been among the most hotly debated issues in the natural sciences. This debate is fueled by the dearth of data on the geology and natural history of Tibet. In addition, Tibet is also the locus of widespread Neogene-Quaternary volcanism and associated geothermal activity, as first noted by *Gansser* [1964].

The great scientific and economic value of Tibet is appreciated by the Chinese, as evidenced by numerous and diverse Academia-Sinica-sponsored expeditions to explore Tibet since 1951. Between 1973 and 1979 an extensive research program was launched throughout the Xizang autonomous region. This program covered the fields of geography, geology, geophysics, biology, and agriculture and involved some 1600 scientists. Foreign scientists participating in the Beijing symposium were impressed by the abundance and the high quality of the data collected by their Chinese colleagues during such expeditions and related studies. Our admiration considerably increased after sensing the delightful effects of high elevation and dry air on the mind and body.

EOS

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Cover. Xigatse Group sediments exposed near Gyantze. Note the spectacular folding. (Photo: Kevin Burke; for story and more photos see article by Şengör, beginning this page.)

Symposium

The symposium began on the morning of May 25th with the opening ceremony in the grand meeting hall of the Jing Xi guest house, which contained both the symposium meeting rooms and all the participants' living quarters—a convenient arrangement. During the ceremony the noted Quaternary geologist, Liu Tung-sheng, secretary-general of the organizing committee, read an informative summary of past Chinese research on the plateau. Following the ceremony, the participants were divided into 10 sections which corresponded with their fields of specialty: geology, geophysics, geochemistry, stratigraphy and palaeontology, zoology, botany, physiology, geomorphology, geography, and meteorology. Every section had an appointed Chinese secretary and a special interpreter who was responsible for simultaneous translations. Before lunch, the sections held a meeting each, during which the members introduced themselves to the entire group.

The symposium had a number of plenary sessions and numerous special sessions. During the first plenary session, on the afternoon of May 25th, Wen Shixuan and Chang Chengfa each read a paper on the stratigraphic and tectonic development, respectively, of the Qinghai-Xizang (Tibet) plateau. These papers provided an excellent background for the rest of the geological discussions during the symposium. The Swiss veteran, Augusto Gansser, followed these theme-setting contributions with a lucid and highly informative summary of the orogenic history of the entire Himalaya.

Although some of them overlapped, a total of nine sessions had papers read by scientists from the geology section, and six contributions came from the stratigraphy and palaeontology section. The geology papers elaborated on the stratigraphic subdivisions of Tibet and their evolution, the structure of selected areas (mainly along the southern boundary of the plateau, i.e., along and near the Yarlung-Zangbo suture zone), and metamorphic and magmatic evolution of the studied regions. Foreign contributions concentrated more on extra-Chinese Himalaya and their surroundings, with few on Tibetan analogs. We learned some important details about the tectono-stratigraphic regions of Tibet and surrounding areas, such as the location, nature and age of belts of granitic intrusives in these various regions, general characteristics of the sedimentary rocks in various parts of Tibet, and the timing of geological events. A repeatedly stressed observation was the large-scale north-vergent structures along the northern boundary of the Yarlung-Zanbo ophiolitic suture. These were interpreted as indicating an original south-dipping subduction zone, or later northward overturning, and *retrocharriage*.

Ten papers discussed the properties of the Xizang geothermal province, which extends for 1000-km parallel with the trend of the Himalaya and irregularly for hundreds of kilometers into the Xizang Plateau. It is by far the largest continental geothermal province in the world and its thermal and geochemical (including isotopic) properties are beginning to be studied closely. An interesting idea reported at the symposium was that the saline lakes of northern Xizang were associated with older, now waning or extinct, geothermal areas. Only the Yangbaijing geothermal field 90 km from Lhasa is exploited for electricity on an experimental basis. This field is estimated to have a potential of 15.5 $\times 10^4$ kW.

The distribution of fauna and flora of late Palaeozoic age and the determination of the northern boundary of Gondwanaland were among the more popular topics in the geology and stratigraphy and palaeontology sessions. The majority of the Chinese specialists (particularly Li Xinxue and Hsü Jen) preferred to draw the northern boundary of Gondwanaland at the Indus-Yarlung-Zangbo suture; others, including many foreign scientists, pointed out the remarkable stratigraphic similarities of Palaeozoic successions and early Palaeozoic tectonic events north and south of the suture and suggested that the boundary should be drawn either along the Tanggula ophiolitic zone (Chang Chengfa), or perhaps better still, farther north along the Hoh Xil Shan (Kokohsili Mountains) (A. M. C. Şengör). The proponents of the latter two views (also J. M. Dickins) pointed out that the Gondwana and Cathaysia floral boundary may have been climatically controlled and that farther west in southeastern Turkey they are known to be mixed, seriously diminishing their value as reliable palaeobiogeographic tools.

The evolution of granitic and granodioritic terrains in Tibet seems to provide further support for *Chang Chengfa and Chen Hsilan's* [1973] earlier thesis that the basement of the plateau was built by the successive accretion of continental pieces to Asia. To the south of the Permo-Triassic volcanic belt in the Hoh Xil Shan is a major belt of predominantly granodioritic and associated magmatic rocks which have isotopic ages around 170 m.y. This belt parallels and is located just to the north of the Tanggula ophiolitic zone. South of this suture is a belt of 130-m.y.-old biotite granites. South of these are the late Cretaceous-Tertiary granodiorites, diorites, and associated rocks of the Kangdese (Transhimalaya) magmatic arc. South of the Indus-Yarlung-Zangbo are the younger Largo-Gangri granites (50–30 m.y.) and the very young (23–16 m.y.), high-K, tourmaline 'hair' granites of the high Himalaya.

Postcollisional evolution of the plateau has involved much north-south shortening and uplift. There was general agreement that the present elevation of Tibet and the Himalaya was the result of an end-Pliocene phase of uplift, which seems still in progress.

This latest and major spasm of uplift has been dissected into finer episodes (namely end Pliocene-beginning Pleistocene and early-Pleistocene and end medial-Pleistocene) by geomorphological methods. Most of the plateau appears to have been subaerial during and after the Eocene, as evidenced by lacustrine deposits of this age (apparently just after the collision along the Indus-Yarlung-Zangbo suture), but these surfaces did not go above 1000-m elevation until the end of the Pleistocene. In a most interesting account on the structural setting of lakes in Tibet, Chen Zhi-ming argued that the majority of the present lakes on the plateau were located in generally north-south-striking grabens, east-west-striking ramp basins, or diagonal 'shear belts.' When coupled with recent accounts on the folding of Neogene strata on the plateau, this picture indicates that until at least very recently active north-south shortening, thickening, and synchronous east-west extension of the plateau have been going on.

During the symposium, participants were presented with copies of a volume of abstracts (English version for the foreigners, Chinese version for the natives); a scientific guidebook to south Xizang, to the area to be covered by the postsymposium excursion; and a superb shaded relief map of Tibet (scale 1:3,000,000). On display in conference rooms were prepublication copies of the newest geological and tectonic maps of Xizang and maps showing the distribution of metamorphic and igneous rocks and their types. A bookstand set up in the first floor of the Jing Xi Guest House offered for sale not only extra-copies of the abstracts volume, the guidebook, and the relief map of Tibet, but also other books of interest to the conference participants.

Large amounts of geophysical data and interpretations were presented by both Chinese and foreign scientists. Teng Ji-wen and his colleagues from the Changchun Geological Institute, Institute of Computing and Techniques of the Ministry of Geology of China, and the Institute of Geophysics of the State Seismological Bureau reported a north-south seismic refraction profile from Dam-Xung to Yadong revealing internal continental structure and a Pn velocity of 8.15 km/s beneath the Moho. North of the Yarlung-Zangbo suture the Moho lies at a depth of 80 km but rapidly shallows to about 45 km to the south of the Himalaya. A low-velocity zone of 5.64 km/s was found within the continental crust at a depth of 40 to 60 km north of the suture; this zone shallowed to about 30 km to the south of the suture.

Gravity work indicates very large positive isostatic anomalies over the higher Himalaya (+120 mGal near Mt. Everest) that decrease to 0 at the Yarlung-Zangbo suture. The Chinese geophysicists (Tang Bo-Xiong and his coworkers) interpret this as the Himalaya's not yet being in isostatic equilibrium. They point out the possible absence of a 'mountain root' beneath the Himalaya.

Aeromagnetic coverage shows the existence of a prominent, continuous anomaly over the Yarlung-Zangbo suture that is interpreted to be indicative of a steeply south-dipping source. Similar but less prominent and less continuous anomalies characterize the Tanggula ophiolitic belt. The aeromagnetic signatures on both sides of the Tanggula belt seem very similar.

There were four papers on surface wave dispersion, three by foreign authors and one by the Chinese. The Chinese study used only the station at Lhasa and considered only paths confined to Tibet. Their study could not resolve crustal thickness or upper mantle velocity. The three foreign studies considered longer periods, and all three suggested a thick crust. Chen and Molnar tried to restrict the paths to the plateau, whereas Knopoff and Teng used long paths and regionalized the velocity distribution, i.e., solving for the velocity structure for each path. Knopoff and Teng obtained somewhat lower velocities than did Chen and Molnar in the upper mantle.

Chinese scientists reported palaeomagnetic data from Late Jurassic and Cretaceous rocks. Data south of the suture of Yarlung-Zangbo showed that these rocks had been a part of the Indian subcontinent. The Cretaceous data from the north of the suture had considerable scatter and indicated little northward motion.

A total of eight sessions were devoted to geomorphology. They were dominated by glaciological research involving the present glaciers of the plateau, past glaciations, periglacial features, and permafrost. Interesting observations were reported about the profiles of major rivers containing major *knickpunkte*, which were interpreted to indicate the episodic uplift of the plateau since the Pliocene. Disparity in numbers of the Pleistocene glaciations on the plateau and on the Himalaya seems to point to differential uplift of the two regions. The present trend of the evolution of the glaciers on the Qinghai-Xizang (Tibet) plateau indicates an overall retreat, although some glaciers are advancing. Another interesting morphological aspect of the plateau is the extent of the permafrost zone on it. Tibet has 70% of the total permafrost surface in China and contains a remarkable assortment of periglacial landforms.

The symposium's heavy technical schedule was punctuated by pleasant tourist excursions in and around Beijing: to the imperial summer palace, to the 'Forbidden City,' to the Ming tombs and the Peking Man site, to Chinese opera and other folkloric performances, to superb lunches at famous 'Peking Duck' restaurants, and finally, to an evening reception at the Great Hall of the People, hosted by His Excellency Senior Vice-Premier Deng Xiaoping, whose presence alone emphasized the significance and historical importance of this unique symposium.

Field Excursion

On June 2nd, those scientists who were going on the field trip to southern Tibet flew from Beijing to Cheng-tu. Early on the following day the party left for Lhasa. The flight from Cheng-tu to Lhasa was a spectacular one. As we left the Szechwan basin, the topography became extremely rugged, with predominant, what seemed to be red, brown, and grey, sandstone-shale (?Permo-Triassic flysch of the Songpan-Ghanzi system) and light grey to light

Fig. 1. Sharp unconformity between the folded Aptian to Cenomanian Takena Formation and the overlying late Cretaceous to Eocene Lingzizong Formation. Exposed on the road from Lhasa to Yangbaijin. (Photo: A. M. C. Şengör)

brown, probably Permian, limestone lithologies. As one approached the plateau proper, extensive erosion surfaces gradually replaced the sharp 'Alpine' morphology. These surfaces appeared to have been very recently dissected and tilted. We noted what seemed to be active, probably strike-slip, fault traces, which, including those of the Kangling fault, particularly excited Paul Tapponnier. Here, as well as in the Alpine terrain of Songpan-Ghanzi, lithologies seemed complexly folded. Farther into the plateau we saw, despite the increasing cloud cover, some truly spectacular valley glaciers carrying a very large load of surface moraines. Finally, the plane descended into the Yarlung-Zangbo valley, where we were treated to a magnificent procession of active latitudinal dunes that locally disintegrated into small barchans.

The field party was driven to Lhasa in a sizeable caravan that consisted of Chinese jeeps and Toyota 20-seat buses. We crossed the Yarlung-Zangbo River over the Quxu bridge and entered the valley of the Lhasa River. A considerable portion of the way we passed through a terrain composed largely of the intrusives of the Kangdese magmatic arc, the older diorite-granodiorite complexes (isotopic ages 79–82 m.y.) to the south of the Yarlung-Zangbo River and the younger granodiorite-granite intrusives (30–40 m.y.) to the north. In the Lhasa valley Triassic-Jurassic, meta-sedimentary rock lithologies are intruded by the granites; the ages of these supposedly nonfossiliferous rocks are based solely on lithologic correlations with fossiliferous rocks farther north. However, at the Lhasa cement works (to the southwest of the city), we were told of the existence of Late Jurassic gastropods.

In Lhasa, we were quartered in a government guest house. The rest of the first day was spent acclimatizing to the formidable elevation. Many of us suffered from headaches and nausea, and a few from more serious lung problems. The second day was also set aside to allow the lowlanders to get used to the high elevation and the remarkably dry air, but this time with the excuse of visiting the Potala palace and the Jokkang, the principal temple of the city.

On June 5th the field party traveled to the Yangbaijin geothermal field, some 90 km northwest of Lhasa. This field lies within a northeast-striking graben that is limited by the ?Precambrian basement of Nyainqentangla Shan to the northwest and Permo-Carboniferous slates, quartz schists, and marbles to the Tang Shan, unconformably overlain by Eocene volcanics, to the southeast. The graben itself contains a fill of Plio-Pleistocene glacial, lacustrine, and fluvial sediments.

The geothermal area of Yangbaijin (about 15 km^2 in area) now contains 10 wet steam wells (one of which has a curious geyser behavior, with regular eruptions at every 12 minutes) and a sulphur mine along the master fault that separates the basin from the Nyainqentangla Shan. In the altered moraines and the brine sinters we saw abundant evidence of very young faulting with rather complex geometry. This experimental field is planned to supply power to Lhasa from the Yangbaijin area in the near future.

Along the road from Lhasa to Yangbaijin, two volcano-sedimentary formations crop out. The older one, called the Takena Formation, is of Aptian to Cenomanian age and consists mainly of shales, sandstones, and argillaceous limestones. This formation is overlain uncomformably by the predominantly volcanic and volcaniclastic lithologies of the Lingzizong Formation of late Cretaceous to ?Eocene age (based on rare vertebrate fossils). Although volcanics had not been previously reported from the Takena Formation, a hornblende-andesite was found along the road. Robert Shackleton thought it was clearly beneath the unconformity separating Takena fom Lingzizong.

The Yangbaijin geothermal field is one of a very large number of active hydrothermal regions located in the Himalayan geothermal belt that very faithfully follows the Indus-Yarlung-Zangbo suture from about Kashmir to the eastern syntaxis. The existence of this belt indicates, although there are no active volcanos present, the presence of magma at no great depth.

After having studied the geology near Lhasa, and some of the Cretaceous intrusives near the Quxu bridge, the field party departed for Xigatse, traveling through Gyangze and Bainang. To the southwest of Quxu, the Yarlung-Zangbo ophiolitic belt has a discontinuity, and one goes directly from the intrusives of the Kangdese belt to the Triassic clastics of the Tethyan Himalaya. The Triassic sediments are predominantly of turbiditic origin, contain the bivalve Halobia, and are most probably equivalent to the so-called Lamayuru 'flysch' of the Zaskar Range just south of Ladakh. Flysch is certainly a misnomer for these rocks because they were possibly deposited along the southern, Atlantic-type continental margin of Neo-Tethys, most likely as continental rise aprons, when there was no sign of orogenic deformation. There were some diabase outcrops within the Triassic sediments near the lake complex of Yamzhog Yum Co, and shortly thereafter we also encountered some silicic dykes.

The clastic facies of Triassic seems to have persisted into the Jurassic, and we saw this Jurassic 'flysch' as well. These rocks are all strongly deformed with fold-axes trending about 55°–60°. In the Karila Pass (5045 m above sea level), apparently organic-rich black shales crop out. They were viewed as possible correlatives of the famous Spiti Shale (Tithonian to Valanginian). In the Karila Pass we were also treated to a magnificent view of a hanging glacier coming down Mt. Noijinkangsang and reaching nearly to the road.

Two parallel, roughly north-south-striking, normal faults bound the massifs on which the Karila Pass is located to the west. These normal faults generated much excitement as at least one of them showed evidence of recent movement in a ground break. Some others in the party were more excited by the spectacular Cretaceus mélange, which contained massive pelagic limestone, radiolarite, and ophiolite blocks of the same age embedded in a coeval pelitic matrix. A heated discussion promptly arose between those who regarded the whole section as of tectonic origin and those who were more sympathetic towards a sedimentary origin. This lasted until Gansser's authority intervened in the form of a diagram sketched on the dirt of the unpaved road with the handle of his handsome and very practical mini-ETH hammer.

The spectacular ophiolite exposures of Bainang separate the sediments of the Tethys Himalaya to the south from the sediments of the Xigatse Group to the north. The Xigatse Group (see cover photo) strongly attracted the palaeontologist members of the field party from the start, and, unable to resist it, E. Kauffman, R. Schroeder, and D. Herm formed a small subgroup with their Chinese colleagues, Yin Jixiang and Wu Haoruo, to devote the entire time we spent in Xigatse and the surrounding area to the study of the Xigatse Group. Their results represent one of the most significant, and somewhat unexpected, accomplishments of the excursion and will soon be reported in a joint publication. *Bally et al.* [1980] had previously compared the Xigatse Group with the Great Valley sequence of California and interpreted it to be an arc-trench gap assemblage. The stratigraphic studies of our palaeontologists revealed the entire sequence to be confined essentially to the medial Cretaceous, and to increase the mystery even further, the early structures of the Xigatze Group turned out to be mainly north-vergent! In some places a clear two-phase deformation is seen, and this contrasts with structures indicating a simpler history elsewhere. Sediments in the Xigatse Group are predominantly medial to distal turbidites, with lesser 'basin deposits' (black shales) and limestone. Although the forearc setting of the whole ensemble seems clear, its exact tectonic evolution still waits to be worked out.

On June 8th the entire day was devoted to the study of the ophiolites and their contact relations with surrounding lithologies near Bainang. In the small dry valley just southwest of the town of Bainang the following section was observed:

From South to North:

1. *Triassic clastics* [illegible] contact with the next unit. Along the very steep (nearly vertical to very steeply south-dipping) thrust is a serpentinite silver, and near it country rock on both sides of the thrust seems highly cataclasized.

2. *Liuchu Conglomerate.* This red-green terrestrial unit is said to be Oligo-Miocene in age, based on fossil teeth finds. In one place where we saw its lower contact with the next unit (the pillow lavas of the ophiolites), it appeared as a thrust. The observation (by Ian Gass and Robert Shackleton) that the pillow lavas were upside-down very near this contact was consistent with the thrust interpretation.

3. Structurally below the Liuchu Conglomerate is the highly dismembered ophiolite together with its epiophiolitic sediments. The ophiolite here consists of serpentinized harzburgites, subordinate gabbros, and pillow lava, whereas the associated sediments are radiolarites and red deep-sea muds.

The steeply south-dipping thrust separating the Triassic clastics from the conglomerates itself is cut by a much more gently south-dipping thrust that seems a very late phenomenon. This rather consistent southerly dip of the structures in the suture belt is not confined to the Chinese Himalaya but manifests itself in the central part of the suture as Gansser reported nearly half a century ago and is also seen in the Zaskar Range south of Ladakh.

The next day we walked along the Qema-Congdu section, some 18 km to the southeast of Xigatse, where again the major lithologies (from south to north: Triassic clastics, well-bedded conglomerates, radiolarites, harzburgites, gabbros, and finally, volcanics) were all dipping south. The radiolarite/harzburgite contact was marked by a conspicuous ophicalcite horizon, possibly a result of synobduction tectonism. Particularly at the southern end of the Qema-Congdu section, we saw older, south-vergent thrusts being cut and displaced by younger, north-vergent ones, possibly indicating an earlier period of southward movement before the now dominant north-vergent structures originated.

On our way back to Xigatse we also found some rather well-preserved sheeted dykes, thus completing the ophiolite sequence. In the Bainang ophiolites there were some diorite-breccias that resembled the hydrothermal breccias known from other ophiolite complexes in the world.

On the 10th of June we visited the Permian exotic blocks outcropping near the Cuola pass, which are associated with the Triassic clastics and complex mélange along the road. The great importance of these exotic blocks is (as in Ladakh) in the evidence they contain for the Triassic extension associated with the opening of Neo-Tethys. Almost exactly as in the case of the early Jurassic Alv or Arzo breccias from the eastern and the southern Alps, here we noted the development of in situ breccias via extensive fissuring of a previously extensive neritic carbonate platform and the infilling of the fissures by younger, deeper-water sediments as the stretched and disintegrated platform subsided. In two outcrops, mafic volcanics were seen in stratigraphic contact with the Permian neritic limestones. The fact that these 'Permian exotics' are now found embedded in the Triassic clastics (?continental rise aprons) further supports the idea of a Triassic rifting and the establishment of a passive continental margin on the northern edge of the Indian subcontinent.

Fig. 2. Permian exotic block within the Triassic [illegible] clastics [illegible] of the Cuola Pass. (Photo A. M. C. Şengör)

Forum

An Investment in AGU—A Comment From a Federal Scientist

In our country, progress in the geophysical sciences has been closely interwoven with progress of the many geophysical activities within the federal government. Substantial numbers of geophysicists traditionally have found their life's work in the ranks of the federal service, where they pursue scientific advancement in their field of work, in laboratory research, and in the management of geophysical science programs.

AGU GIFT 1980 198[illegible]

To this large body of scientists the American Geophysical Union has always been a helpful and needed scientific organization. Access to high-quality journals is undoubtedly the most useful and cherished AGU benefit provided to the federal employees. Next in importance may be the many, many benefits that come by participation in the AGU scientific meetings. This is followed by opportunities afforded federal scientists to serve in policy and administrative roles on the committees and council of the Union. These AGU benefits, and many more not enumerated here, can bring an abundance of national recognition, intellectual maturity, and self-esteem to federal scientists, thus encouraging us to become better scientists and more proficient employees.

Strengthening the AGU by giving it greater financial integrity is of prime interest to each and every member of the AGU, including geophysicists in the federal service. AGU works for us. A personal investment in AGU, during the present funding campaign, will assure that the work of the AGU continues and that the AGU will be there to work for the federal geophysicists who follow in our ranks.

Ned A. Ostenso
Director of Sea Grant Program, NOAA

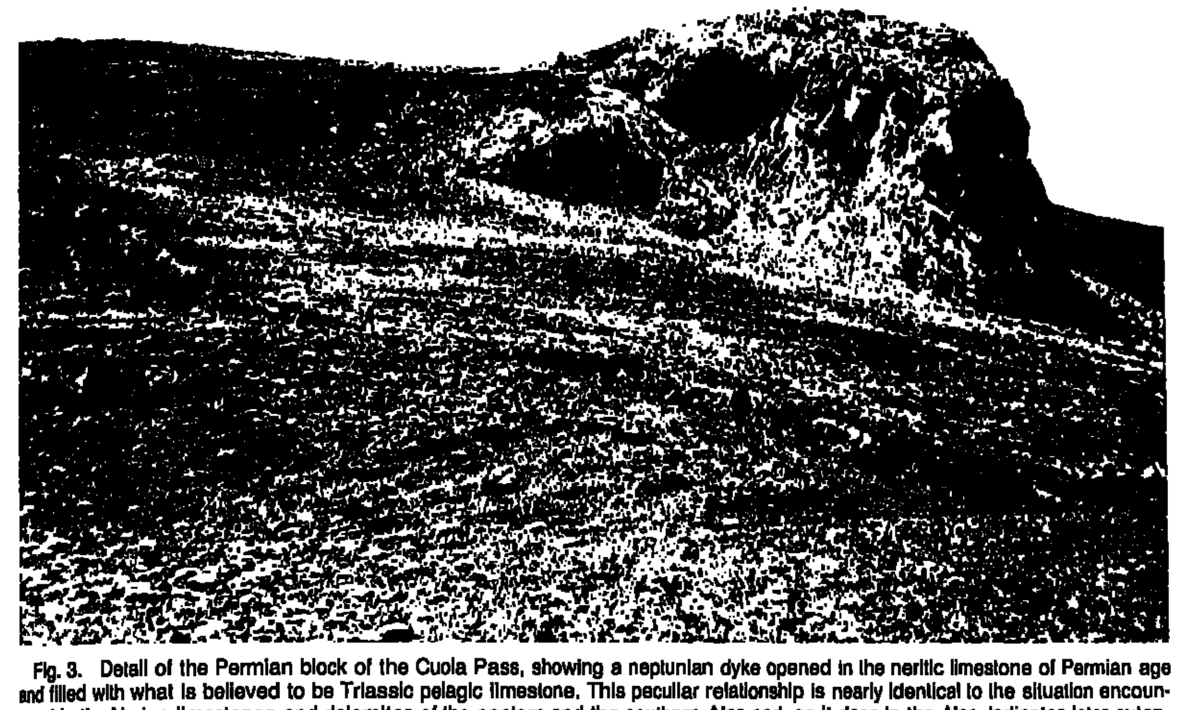

Fig. 3. Detail of the Permian block of the Cuola Pass, showing a neptunian dyke opened in the neritic limestone of Permian age and filled with what is believed to be Triassic pelagic limestone. This peculiar relationship is nearly identical to the situation encountered in the Norian limestones and dolomites of the eastern and the southern Alps and, as it does in the Alps, indicates later extension and subsidence of a neritic carbonate platform. (Photo A. M. C. Şengör)

Fig. 4. View of the Potala from the ruined tower of the Medical School in Lhasa. In the background are the young granites and the Triassic and Jurassic metasediments. In the foreground, Augusto Gansser is giving scale. (Photo A. M. C. Şengör)

On June 11th we arrived at Tingri, and after a one-night stay continued to our final destination in China, Zham. During these last 3 days of the field excursion, we spent most of our time studying the Palaeozoic and Mesozoic sediments and Palaeozoic and Precambrian metamorphics of the Tethys and the High Himalaya. The spectacular tourmaline granites added much color to the last days' outcrop hopping.

On June 13th, during the afternoon, a general meeting was held in Zham, where individual specialist groups reported, through spokesmen, their overall impressions of the excursion. I summarize here briefly the reports of the solid earth scientist groups.

1. *General geology.* Patrick Le Fort (France) opened his remarks by expressing the general feeling of admiration of the foreign scientists for the enormous amounts of work accomplished by their Chinese colleagues in a relatively short time. He praised the careful stratigraphic studies and pointed out how quickly and accurately our enquiries concerning stratigraphy had been answered by our hosts throughout the trip. He underlined the importance of structural mapping and wished that more emphasis could be laid on structural work in future studies so as to complement the stratigraphic information. He stressed the role of igneous petrology and geochemistry as tools for our understanding of crustal and mantle evolution and emphasized how critical good geophysical data (seismic, gravity, magnetics, and leveling) were in our efforts to paint a picture for the current tectonics of the plateau.

2. *Stratigraphy and palaeontology.* Erle Kauffman (USA) pointed out that although palaeontologists represented a very small group in the field party, it nevertheless was a diverse one, with people having different research experiences. They essentially 'went down the stratigraphic column,' pooled their data, and regularly discussed their observations. Their greatest gains were from the Mesozoic, particularly from the Cretaceous. He gave their study of the Xigatse Group as an example. In the opinion of foreign palaeontologists what was now needed was a greater number of detailed observations. Although the existing Chinese basis for stratigraphy was excellent, selected sections with good fossil control and as complete a record as possible should be studied in detail for every period, and these should become reference sections. Such studies should encourage more integration among specialists. They also felt that perhaps more specialists for micropalaeontological research were necessary. Finally, Kauffman stressed the necessity of addressing specialized problems with well-formulated questions in mind and gave the problems of the determination of the northern boundary of Permian Gondwanaland in China as an example.

3. *Quaternary geology.* Troy Péwé (USA) concentrated mainly on glacial and associated phenomena. He said that few glaciers were actually seen during the trip. He emphasized the role of satellite imagery for glacial studies and praised the quality of Chinese glacial maps. Great dissection by glacial or other kinds of streams was noted. Future studies should, in his opinion, try to see why that was so. He remarked that terrace studies would be interesting for obtaining uplift rates.

In the terrain we covered, periglacial phenomena were not widespread, and Péwé ascribed this paucity to the fact that the region had been dry. Observed pulsas (peat mounds; first recognition in Tibet) were good indicators of permafrost (found here at 4900 m).

Much of the agriculture in the areas we visited was found to be on retransported loess. Most of the deposits previously believed to have been lacustrine were probably loess, and Péwé stressed the importance of loess as a repository of Quaternary fossils.

In other branches, S. Dillon Ripley (USA) of the Smithsonian Institution, our senior spokesman, reported for zoologists, with assistance from Roman Zink (Federal Republic of Germany) in the name of the physicians, C. Jest (France) for geographers and botanists, E. Reiter (USA) for meteorologists, and Jack Ives (USA) for applied geomorphologists.

The day ended with a colorful closing party, where, among others, 'Babay Himalaya' Gansser gave a very brief but animated speech, thanked our hosts, and wished for more future collaboration. Toward the end it was clear to all that this historic event was closing as a great achievement of international science and as a tribute to its creators. On June 14th the majority of the foreign scientists left for Nepal, where they were welcomed by the Nepalese Geological Society, which had arranged transport to Khatmandu across the Friendship Bridge, while a handful began their return journey back to Beijing.

Acknowledgments

I thank Peter Molnar for his help in summarizing the geophysical information. A very thorough review by Erle Kauffman greatly improved the presentation.

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A. M. C. Şengör, a citizen of Turkey, was born in Istanbul in 1955. He completed his primary and secondary education there. After having spent a year (1973–1974) studying German and geology in Munich and Berlin (Germany), he received his formal university education in Houston, Texas and Albany, New York, graduating from the State University of New York in Albany in 1978 with a B.S. in geology. He received his M.S. degree from the same institution in 1979. He is currently working on his Ph.D. there. Şengör's main interests are field structural geology and theoretical and regional tectonics. Since 1975 he has published some 30 papers on these and other fields in geology. In 1976 he was awarded the Best Student Paper Award of GSA-South Central Section and the Outstanding Student Award of the Houston Geological Society.

News

Looking Ahead to Voyager 2

Voyager 2 will whiz past Saturn late next month, giving scientists yet another look at the planet's intricate ring system, its satellites, and the atmosphere. The encounter will concentrate on selected targets, though, rather than take a sweeping look at the entire Saturnian system, as Voyager 1 did. Voyager 2 will take higher-resolution photographs of five satellites—Enceladas, Tethys, Iapetus, Hyperion, and Phoebe—than did its sister ship. Higher-resolution pictures of the rings also are expected.

Closest approach to the planet will be on August 25 at 8:25 P.M. PDT (11:25 P.M. EDT). Transmission of signals from the spacecraft to earth will take nearly another hour and a half.

One of Voyager's most important observations, according to NASA spokesmen, will be an occultation or eclipse of the star Delta Scorpii by Saturn's rings. For about 2 hours during the late afternoon on August 25, shortly before closest approach to Saturn, the photopolarimeter will be aimed so that Saturn's rings pass between it and Delta Scorpii. As the ring material appears to make the star blink on and off, the instrument is expected to count, with high precision, the number of ringlets. Sizes of the ring particles will be measured to an accuracy of ½ km. The ring section to be used in this experiment will be in Saturn's shadow, so there should be little interference from scattered sunlight.

In addition, stereo images will be taken of the braided F-ring to determine if the braid is two- or three-dimensional, according to Edward C. Stone, Voyager project scientist. 'We will investigate the structure of the braiding in the vicinity of the shepherding satellites and search for any changes in the braiding when in Saturn's shadow, as might be expected if electrostatic charging is important,' he said.

Voyager will approach Saturn from above the ring plane, with the sun behind it. Observations of the rings will be entirely on the sunlit side. Voyager will cross the ring plane only as it departs for Uranus. As it crosses the plane, a camera will take a series of pictures of the B-ring to determine if any material is elevated above the main ring structure. One theory postulates that small particles elevated above the ring plane may account for the appearance of 'spokes' seen in the ring as it rotates out of Saturn's shadow.

Other highlights of Voyager 2's encounter with Saturn include better-resolution maps of Saturn, deeper radio penetration of Saturn's atmosphere, better information on Saturn's aurorae, and closer examination of eccentric ringlets in the C-ring.—*BTR*

Geophysics Publications Honored

Geophysics and geology publications by the U.S. Geological Survey were awarded one first- and two third-place prizes at the 'Blue Pencil' ceremony last month, sponsored by the National Association of Government Communicators.

First place in the news release category went to Frank Forrester, an AGU member and recently retired USGS information officer. Editors and artists of the bimonthly *USGS Earthquake Information Bulletin* were awarded third place in the category for technical magazines using at least two colors. AGU member Henry Spall is the editor of that publication. Also receiving a third-place award was David Delaney, for graphic design of a groundwater hydrology map/report of Martha's Vineyard, Mass.

Fund Honors Jule G. Charney

The Department of Meteorology and Physical Oceanography at the Massachusetts Institute of Technology has established a fund in honor of the late Jule G. Charney. Charney died in Boston last month (*Eos*, July 7). Income from the fund will be awarded to meritorious students for graduate study in the department. The awards will be known as the Jule G. Charney Awards.

Anyone wishing to contribute to the fund may send a check, made out to the Jule G. Charney Fund, to the Department of Meteorology and Physical Oceanography, MIT, Room 54-1712, Cambridge, MA 02139. All gifts will be tax deductible.

Geophysical Events

This is a summary of *SEAN Bulletin, 6*(6), June 30, 1981, a publication of the Smithsonian Institution. The complete bulletin is available in the microfiche edition of *Eos*, as a microfiche supplement, or a paper reprint. For the microfiche, order document number E81-004 at $1.00 from AGU, 2000 Florida Avenue, N.W., Washington, D.C. 20009. For reprints order *Sean Bulletin* (give dates and volume number) through AGU Separates: $3.50 for the first copy for those who do not have a deposit account; $2 for those who do; additional copies are $1.00. Orders must be prepaid.

Volcanic Events

Mt. St. Helens (Washington): Lava extrusion adds 5th lobe to crater dome.
Kilauea (Hawaii): Small shallow intrusion under SE part of caldera.
• Bezymianny (Kamchatka): Large tephra cloud and lava flow.
Pagan (Mariana Islands): Renewed explosions on June 11.
• Aso (Japan): 30-minute ash and block ejection.
Sakurazima (Japan): Fewer explosions.
Bulusan (Philippines): Earthquake swarm.
Mayon (Philippines): Mudflows from typhoon rains.
• Langila (New Britain): Increased ash emissions, glow, lava fragments.
Manam (Bismarck Sea): Ash emission continues; rumblings.

Bezymianny Volcano, Kamchatka Peninsula, USSR (55.97°N, 160.59°E). In a report dated June 16, the Soviet news agency Tass said that Bezymianny had erupted, ejecting an 8-km-high ash column and extruding a lava flow 400 m wide. National Earth Satellite Service personnel inspected early- and mid-June imagery, returned every 3 hours from the Japanese geostationary weather satellite, but did not find a large eruption column. Weather is often cloudy over the Kamchatka Peninsula, however, and could have masked evidence of an eruption.

Information contacts: Earl Hooper, NOAA/National Earth Satellite Service, Synoptic Analysis Branch, S/OP33, Camp Springs, Maryland 20233 USA; Tass, Soviet News Agency.

Aso Volcano, Kyushu, Japan (32.90°N, 131.10°E). All times are local (GMT + 9 h). Ash and block ejection from Crater 1 in Nakadake was observed from 1230 to 1300 on June 15, after 9 months of quiescence. Blocks rose to 30 m but fell within the 100-m diameter crater. One-micron ground shocks were recorded at 1239 and 1244, and a 3.7-micron shock at 1251. Activity then subsided. The explosions caused no damage. The area within 1 km of the summit, closed immediately after activity began, was reopened June 17. The last prior eruptive activity was a brief ash ejection on September 24, 1980 (see *SEAN Bulletin, 5* (9)).

Asosan Weather Station personnel observed that the greenish water, pooled in Crater 1 since October, became gray tinted. The water rose intermittently.

Nakadake is the historically active part of the Aso volcanic complex. Crater 1, the northernmost of seven in Nakadake, has been the source of Aso's recent eruptions.

Information contact: Seismological Division, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100, Japan.

Langila Volcano, New Britain Island, Papua New Guinea (5.53°, 148.42°E). The following is from the acting senior volcanologist:

> A further intensification of activity took place in June. Moderate to strong white and brown emissions from Crater 2 were commonly seen. Ash falls were reported on several days from locations about 10 km from the volcano. Rumbling and/or explosive sounds were heard on most days. Crater glow or ejections of incandescent lava fragments from Crater 2 were seen on 5 days in the second half of the month. Crater 3 was less active, commonly releasing white or blue vapours, but weak grey emissions were occasionally seen.
>
> Seismic activity strengthened considerably. Large-amplitude, multiple explosion type earthquakes and prolonged periods of tremor clearly represented tephra explosions and bouts of gas venting at Crater 2.

Information contact: Acting Senior Government Volcanologist, Rabaul Volcano Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Earthquakes

Date	Time, GMT	Magnitude	Region
June 11	0724	6.9 M_s	SE Iran
June 13	0729	5.4 m_b	W China
June 16	2134	5.3 M_L	SE Australia
June 22	1753	5.0 M_s	Central Peru

Latitude	Longitude	Depth of Focus
29.98°N	57.72°E	shallow
36.22°N	76.79°E	79 km
34.84°S	144.30°E	shallow
13.37°S	74.70°W	shallow

The June 11 earthquake in Iran's Kerman Providence left at least 3000 persons dead, thousands more hurt, and virtually destroyed the village of Golbaft, about 850 km SE of Teheran. One died and two were injured in NE Afghanistan June 13; the earthquake was centered in SW Sinkiang Province, China, about 500 km NE of Rawalpindi, Pakistan. No damage or injuries were reported from the June 16 event, which occurred in the Bass Strait between Melbourne and Tasmania. The June 22 shock killed six persons, injured dozens, damaged many buildings, and triggered earth slides which blocked roads and the main water-supply canal in the town of Ayacucho, about 300 km SE of Lima. In April a magnitude 5.1 earthquake jolted the same general area (see June 9 *Eos*).

Information contacts: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225 USA; E. P. Shelley, Principal Information Officer, Bureau of Mineral Resources, Geology & Geophysics, P.O. Box 378, Canberra City, A.C.T., 2601, Australia; Agence France-Presse; New York Times; United Press International; Associated Press.

Meteoritic Events

○Meteorite Fall: Oregon, May 11 or 12
Fireballs: Atlantic Ocean (3), Australia, Austria, Spain, Uzbek SSR

Meteorite Fall

Oregon, May 11 or 12, 0815 GMT (0115 Pacific Daylight Time). Deputy Sheriff James P. Price observed a meteorite strike the roof of his [illegible]. Price collected 61 grams of fragments, [illegible] Battelle Pacific Northwest Laboratory for analysis. The three largest pieces fit together to form most of a roughly ovoid object with a somewhat bubbly fusion crust that ranged from about 1 mm thick on one side to about 3 mm thick on the opposite side. From hand-specimen evaluation, it appeared that ⅔ to ¾ of the meteorite had been recovered and that it had not fragmented before impact. Hand-specimen inspection also indicated that the meteorite is an ordinary brecciated chondrite of either the H or L type.

Information contacts: James P. Price, 4652 Santiam St. NE, Salem, Oregon 97305 USA; J. C. Evans and J. C. Laul, Battelle Pacific Northwest Laboratory, P.O. Box 999, Richland, Washington 99352 USA.

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Geophysicists

Elected as members of the National Academy of Sciences at the 118th annual meeting are *John C. Crowell*, professor of geology at the University of California at Santa Barbara; *Donald M. Hunten*, professor of planetary sciences, University of Arizona; *Champ B. Tanner*, professor in the soil science department at the University of Wisconsin at Madison; and *Hugh P. Taylor, Jr.*, professor in the department of physics and astronomy at the University of Massachusetts at Amherst.

Thomas M. Donahue was awarded the Henryk Arctowski Medal by the National Academy of Sciences at its 118th annual meeting. Donahue was honored for his 'outstanding contributions to the study of solar activity changes of short or long duration and their effects upon the ionosphere and terrestrial atmosphere.' Donahue received AGU's Fleming Medal at the Spring Meeting in May.

Kisslinger

Carl Kisslinger was elected a corresponding member of the mathematical-natural science division of the Austrian Academy of Science. Professor of geological sciences and a fellow of the Cooperative Institute for Research in Environmental Studies at the University of Colorado in Boulder, Kisslinger is AGU's foreign secretary and an officer of the International Union of Geodesy and Geophysics.

Lachapelle

Gérard Lachapelle, Eos associate editor for geodesy, has been elected vice president of the Canadian Institute of Surveying. He is currently head of the Geodetic Research and Development Section at Sheltech Canada in Calgary, Alberta. (Photo credit: Shell Canada Resources Ltd.)

Alan M. Lovelace left NASA earlier this month to become corporate vice president of science and engineering at the General Dynamics Corp. in St. Louis, Mo. He had retired as NASA's deputy administrator in December, but stayed on at NASA through the first flight of the space shuttle. He became acting administrator in January.

Papike

James J. Papike has accepted a professorship in the Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota. In addition, he will be director of a new Institute for the Study of Mineral Deposits (ISMD). Through the institute, Papike plans to launch a 10-year multidisciplinary study of mineral deposits, with major emphasis on the Black Hills of South Dakota. Papike leaves the position of professor and coordinator for geosciences in the Department of Earth and Space Sciences, State University of New York, [illegible] where he has been for 12 years.

New Publications

The Earth's Variable Rotation: Geophysical Causes and Consequences

Kurt Lambeck, Cambridge University Press, Cambridge, England, xi + 449 pp., 1980, $92.50

Reviewed by Michael A. Chinnery

Seldom, these days, does one come across an elegant treatise of the kind that was common 50 years ago, displaying an erudite style, a comprehensive understanding of a wide range of disciplines, and a feeling that almost every page contains the germ of a new research project or Ph.D. thesis. The field of the earth's rotation now has two such treatises. The first was by Munk and MacDonald (*The Rotation of the Earth*, Cambridge University Press, 1960), a work that has been universally accepted as a classic. The second is Kurt Lambeck's new book, which in my view is destined for similar praise.

The field of the earth's rotation is one that has fascinated many of us, partly for the richness and complexity of the problems that it poses, and partly (be truthful now!) because in these mission-oriented days it is one of the few disciplines that appears to have absolutely no application to any important societal problem. Munk and MacDonald produced a quite remarkable review of the field, ranging from the forced and free motions of the earth, through descriptions of the gross deformation of the earth and tidal dissipation, to variations in the rate of rotation of the earth. Their discussion was firmly based on classical mechanics and formulated the basic problems in the field in a satisfyingly rigorous way. However, they were able to say comparatively little about the solutions to these problems because of the small amount of data available at that time.

The field has changed a great deal since 1960, largely as a result of the rapid growth of geophysics as a whole and geophysical instrumentation in particular. We now understand the internal structure and composition of the earth more clearly, the excitation functions due to earthquakes and atmospheric effects can be evaluated using vastly more data, plate tectonics has appeared on the scene, and precise measurements of the rate of rotation of the earth now form a time series over 25 years long. Perhaps even more importantly, we have begun to explore the connections between the various subfields of geophysics. Earthquakes, deformations of the crust and mantle of the earth, continental drift, gravitational forces, motions in the earth's core associated with the magnetic field, and motions in the atmosphere and oceans all interact with each other and all contribute in some way to the rotational dynamics of the earth.

Lambeck traces these complex connections with a masterful hand. After a review of the physical properties of the earth, he formulates the dynamics of the rotating earth and the computation of the various types of excitation functions. He then reviews the nature and extent of data for both length-of-day and polar motion, as a basis for exploring the processes that they represent. The effects of tidal forces, and seasonal variations due to the atmosphere and oceans, are each described in detail. The Chandler wobble, and its excitation and dissipation, receives a thorough review, as do the decade fluctuations in the length of day. Tidal dissipation is discussed at length, and the book ends with a survey of 'paleorotation,' including both long-term changes in the length of day and polar wandering.

In many of the areas covered by this book, Lambeck and his coworkers have made major contributions. I was particularly impressed by the discussion of seasonal variations due to meteorological effects such as the zonal winds and the chapter on tidal dissipation. The whole book, however, is well referenced, and a lengthy bibliography is supplied.

I recommend this book without reservation for anyone involved in planetary astronomy, the energetics of the earth and its internal dissipation processes, and the measurement and interpretation of the earth's rotation. It will make an excellent resource book for many graduate level courses in geophysics and will be particularly valuable as an aid for graduate students engaged in research in geophysics and astronomy.

My main criticism of this book is with regard to its price. The volume is excellently produced and printed, but a price of $92.50 (even given some discounts which may be available) will probably limit its purchase to libraries and the occasional rich geophysicist (there must be some somewhere). This is a pity. I feel the publishers have underestimated the potential sales of this book if the price were more moderate.

Michael A. Chinnery is with the Applied Seismology Group, Cambridge, Massachusetts.

New Listings

Items listed in New Publications can be ordered directly from the publisher; they are not available through AGU.

Underwater Acoustics and Signal Processing. L. Bjorno. D. Reidel, Hingham, Mass., xvi + 736 pp., 1981, $87.00.

Water and Energy in Colorado's Future: The Impacts of Energy Development on Water Use in 1985 and 2000. Colorado Energy Research Institute. Westbrook Press. Boulder, Colo., xiii + 303 pp., 1981, $26.25.

Water in Desert Ecosystems. D. D. Evans and J. L. Thames (Eds.), Academic, New York, xiv + 280 pp., 1981, $35.00.

Wege Aus Der Entsorgungsfalle. SES Rep. 12. V. M. Buser and W. Wildi (Eds.), Schweizerische Energie-Stiftung Zurich, 258 pp., 1981, 20.-- Swiss francs.

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Private foundation funding limits awards to U.S. citizens. Appointments are for one or two years. Applicant should have a background in appropriate physical sciences for work in one of these fields at the Ph.D. level, or equivalent. Appointments in the University of California system will be at the level of Postgraduate Research or Assistant Research, salary from $17,112–28,400, commensurate with qualifications. Submit resume (specify position/field) including names of references, before *Sept. 18, 1981* to: J. D. Frautschy, Deputy Director, A-010, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093. Request position profiles at the same address.

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Visiting Scientist Position/The Joint Institute for the Study of the Atmosphere and Ocean, University of Washington. Visiting scientists with background in atmospheric sciences or physical oceanography and interests in dynamical and/or geochemical aspects of climate variability. Term of appointment: one (1) year, renewable for a second year subject to the approval of the Council. Closing date: September 15, 1981. Send curriculum vitae and a brief research prospectus to Director, JISAO, c/o Department of Atmospheric Sciences, AK-40, University of Washington, Seattle, WA 98195.

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University of Hawaii/Faculty Positions. The Department of Geology and Geophysics and the Hawaii Institute of Geophysics have openings for the 1981–1982 academic year. Rank is open dependent on qualifications. We are seeking persons who will participate in our teaching and research program in any of the following areas: (1) structural geology and marine tectonics; (2) hydrology and engineering geology; (3) marine seismology, magnetics, and gravity. To apply send a letter of interest, a current vita and 3 letters of reference to Dr. S. O. Schlanger, Chairman, Department of Geology and Geophysics, University of Hawaii, 2525 Correa Road, Honolulu, Hawaii 96822 (808-948-7826), or Dr. C. E. Helsley, Director, Hawaii Institute of Geophysics, same address (808-948-8760). Open until filled.

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Faculty Position
Economic Geology

The Department of Geology, University of Georgia, has a tenure track opening in economic geology. Rank and compensation are open through the associate professor level.

Duties include (1) teaching courses in exploration geochemistry (2) supervising M.S. and Ph.D. candidates, and (3) developing a strong research program with significant field commitment.

Teaching and research interests in one or more additional fields such as ore deposit mineralogy, reflected light microscopy, theoretical geochemistry of ore deposits, fluid inclusion research, hydrogeochemistry, or environmental geochemistry are desirable.

An applicant should submit a detailed curriculum vitae and have at least three letters of recommendation sent to the Acting Head, Department of Geology, University of Georgia, Athens, Georgia 30602.

The deadline for receipt of applications is November 1.

The University of Georgia is an equal employment opportunity/affirmative action institution.

Acoustical Physicist. Physics and Chemistry Department of Naval Postgraduate School (NPS), in Monterey, California, seeks applicants for tenure-track position at assistant or associate professor level, physicist who has experience and interest in teaching and research in area of acoustics. Primary mission of NPS is advanced education of Naval Officers. Department offers M.S. and Ph D. degrees in Physics and Engineering Acoustics with major emphasis on Master's degree program. Most acoustics teaching is at senior and graduate level with concentration in underwater acoustics. Candidate must have Ph.D., be effective teacher and be interested in and capable of engaging in research. Current acoustics research areas: ocean acoustics including propagation, ambient noise, scattering and diffraction; propagation in tapered wave-guides; acoustic imaging; signal processing and non-linear acoustics. Send resume and references to Prof. O. B. Wilson, Department of Physics and Chemistry, Naval Postgraduate School, Monterey, CA 93940.

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Research Associate. Two year appointment. Scientific programmer to develop a computer program for simulating water and pollutant movement thru small catchments, using and modifying subroutine and algorithms developed for this purpose by research scientists. Test and evaluate the program, and develop efficient data handing procedures. Refine and evaluate subsections of program in the process of its development. B.S. degree in computer science, mathematics, or a physical science with extensive mathematical and computer applications training. Fortran language programming, experience with the CDC NOS system. Experience in scientific programming required, and understanding of hydrology desired. Salary is negotiable. Application deadline August 14, 1981, position available September 1, 1981. Send letter of application, resume, list of references to: Dr. R. E. Smith, Hydraulic Engineer, USDA-SEA, Department of Civil Engineering, Engineering Research Center, Colorado State University, Fort Collins, CO 80523.

CSU is EEO/AA employer.
E. O. Office: 314 Student Ser. Bldg.

Polar Oceanographer/Sea Ice Dynamicist. A position is available under the Intergovernmental Personnel Act of 1970 for persons now employed in State local government or in colleges and universities. This position is located within the Oceanic Processes Branch of the Environmental Observation Division of the Office of Space and Terrestrial Applications, NASA Headquarters. The position is for one year, with the possibility for renewal for an additional year. Pay will be at a level commensurate with experience, and will be established after a review of qualifications.

Candidates must have been employed by the university in a permanent position for at least 90 days or be a career employee of a State or local government. Candidates must also meet the Federal qualification standards for the position. These are as follows: a degree in an appropriate field of science, plus three years of progressively responsible experience in duties related to the position.

This individual will be responsible for planning, developing, and implementing a scientific research program in satellite remote sensing of oceanic processes in polar regions. A background in polar oceanography, sea ice dynamics, or a closely-related field is required; experience in remote sensing, although desirable, is not essential. A Ph.D. or equivalent training and experience is mandatory.

Interested parties should send a current resume to NASA Headquarters Attn: Mrs. Catherine Zegowitz, Code EPM-3, Washington, D.C. 20546.

Selection for this position will be made from otherwise eligible candidates without discrimination for any nonmerit reason such as race, color, religion, sex, national origin, politics, marital status, physical handicap, age, membership or nonmembership in an employee organization, or personal favoritism.

Electron Microprobe Technical Specialist/University of Colorado. The department of Geological Science, University of Colorado, Boulder, seeks a person who will assume responsibility for the department's electron microprobe laboratory. Duties will include day-to-day operation of our MAC 400 microprobe equipped with a KEVEX EDS system, instruction of new operators, maintenance of the microprobe as well as other X-ray equipment within the Department, microprobe software and hardware development, and participation in research projects involving silicate, sulfide and oxide mineralogy. The job requires either a degree in electronic or electrical engineering, or two years of technical experience utilizing electronic instrumentation associated with an electron column instrument. An individual with an M.S. degree in Geology and microprobe experience will be considered highly desirable. Salary ranges from $20,000–$25,000 depending on experience. Please send, by August 15, letter of application and resume to Bruce Bedger, Personnel Department, University of Colorado, 1511 University Avenue, Boulder, CO 80309.

The University of Colorado is an equal opportunity affirmative action employer.

Head, Department of Oceanography & Ocean Engineering. The Florida Institute of Technology seeks an individual to head a multidisciplinary department of scientists and engineers. Position to commence as early as September 1981. Candidates must possess a Ph.D. degree and have demonstrated meritorious scientific work in oceanography or ocean engineering with interest and experience in teaching, research, and administration. The Department has graduate and undergraduate interdisciplinary programs in biological, chemical, geological and physical oceanography, and ocean engineering. Curricula for the Ph.D. are available in physical, chemical, and biological oceanography. The department is part of a fast rising university in a community on the east coast thriving with technical industries. Benefits include free tuition for family members. Send resume and names of references to: Chairman of Search Committee, Department of Oceanography & Ocean Engineering, Florida Institute of Technology, Melbourne, FL 32901.

Florida Institute of Technology is an equal opportunity employer.

Position Open/Residuals Management Technology, Inc. M.S. in Water Resources Management, with experience in ground water modeling and knowledge of ground water and soil sampling and measuring devices. Provide consulting service on geology and ground water as they relate to solid and hazardous waste disposal. Conduct research on ground water pollution and plan and conduct field investigations of disposal sites including borings and wells. Sample and monitor soils and water and interpret data. Prepare disposal site selection studies and environmental reports. Direct the office and field project work of technicians and interface with engineers on facility design. Provide liaison with clients and regulatory agencies. Develop familiarity with engineering design concepts for land disposal. Full-time, 40-hour week. Salary $1300/month plus eligibility for bonus and profit-sharing plan. Submit application to: Sath Menon, Job Service Wisconsin, 105 N. Broom Street, Madison, WI 53703. (608) 266-2341. This ad not paid for by Job Service Funds.

Atmospheric Scientist/Group Head. Senior staff scientist position available immediately at the NAIC's Arecibo Observatory. The successful applicant will be appointed as Head of the Atmospheric Sciences Group and will be expected to lead that group and to perform independent research using the Arecibo facilities. A Ph.D. degree in atmospheric or physical sciences or radar engineering and a record of solid research accomplishments are required. Experience with radar studies of the stratosphere, mesosphere, and ionosphere or with HF modifications of the ionosphere is desirable. Salary open. Please send resume and names of at least three references to Dr. Harold D. Craft, Jr., Acting Director, NAIC Observatory, Space Sciences Building, Cornell University, Ithaca, New York 14853.

NAIC-Cornell University are EOE/AAE.

National Research Council Canada / **Conseil national de recherches Canada**

RESEARCH OFFICER

The Canada Centre for Space Science of the National Research Council of Canada requires a Research Officer. As a Space Scientist in the Scientific Planning and Evaluation Group, the duties will include:

—Assisting in the evaluation and processing of proposals received by the CCSS for the rocket and balloon program, the satellite program and supporting ground-based experiments.
—Participating in the planning of scientific campaigns forming part of the above programs and in scientific working groups associated with the experiments.
—Perform studies pertaining to monitoring and evaluating the functioning of the above programs as and when required.
—Participating in CCSS national and international committees and working groups as required.
—Participating as an investigator (experimental or theoretical) in CCSS associated scientific programs.
—Performing other associated duties as required.

Preference will be given to candidates having a Ph.D. in Physics with several years' experience in space science or equivalent research experience in space science.

Salary—Up to $30,430 per annum depending on qualifications.

Apply in writing to the Employment Officer, National Research Council of Canada, Ottawa, Ontario, K1A 0R6. In reply, please quote CCSS-81-2-.

Canada

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Early Scientific Instruments. Send $2.00 for illustrated list of antique surveying instruments for sale. Tesseract, Box 161-A, Hastings-on-Hudson, NY 10706.

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Coal Deposits. If you are financing, planning, exploring, drilling, or digging in connection with any form of energy, you need this complete, up-to-date book about the world's coal deposits. Includes production and reserves for mines. Hardcover, 8 × 9 inches, 590 pages. Table of contents, drawings, index, references, 1980. $156. Tatech Associates, Thunder Road, Sudbury, MA 01776, USA.

AGU

The Sixteenth Presentation of the

John Adam Fleming Medal

to

Thomas M. Donahue

for original research and technical leadership in geomagnetism, atmospheric electricity, aeronomy and related sciences

Citation

Citations are supposed to begin with a statement of the sort 'It is an honor and a pleasure for me to introduce. . . .' However, in the case of Tom Donahue I do not think that I have to introduce him, since most everyone here this evening already knows him. His 30-plus-year career spans a very broad field of scientific endeavors as well as numerous institutions. We at Michigan are lucky to have had him with us since 1974. He has made his lasting mark in the field of aeronomy through his publications, which number over 140, his many graduate students, postdocs, and colleagues who have had the good fortune to have worked with him. Sydney Chapman must have been thinking of someone like Tom Donahue when he coined the word aeronomy. Tom was born in Oklahoma, receive his B.A. from Rockhurst College in Kansas City and his Ph.D. from The Johns Hopkins University in 1947. Perhaps it is appropriate that he is now receiving the Fleming Award here in Baltimore, where his professional career began. His deep lifelong involvement in solar system studies really began when he moved to The University of Pittsburgh in 1951, and he has been going full steam ever since.

It is important to also remember and point out that it would take me the rest of the evening to outline Tom's long list of public service activities. He has served on and chaired many committees, panels, boards, etc. His willingness to give his time, his enthusiasm, and wisdom has made the difference between success and failure in many of these endeavors. Those of us who know him closely also know that he is a 'complete human being.' Try to talk to him about literature, music, politics, mushrooms, or wine, just to name a few topics, and you will know what I mean. My only advice to you is do not (1) ask him how to solve the problem in Ireland and (2) let him select your wine, unless you have just won the Irish Sweepstakes.

In conclusion I want to be sure that I am not leaving you with the wrong impression by briefly reviewing Tom's past achievements. He was 60 years young this weekend, and I can assure you that he is only at the halfway mark in his scientific achievements.

Andrew F. Nagy

Acceptance

I am deeply grateful and flattered by the decision of the American Geophysical Union to present this award to me and by the citation Dr. Nagy has just read. Before trying to compose an appropriate response to that citation I naturally rummaged through old issues of *Eos* to discover who were my predecessors and how they had replied to the presentation of the John Adam Fleming Award. My first reaction to what I learned was humility in the first place and, in the second, a temptation to declare 'That's what I was going to say' and sit down. There is a footnote here attributing this statement to Gerald Fink who did precisely that recently at an Academy of Sciences Award Ceremony.

Other Fleming award recipients such as Syun Akasofu and Frank Johnson have indeed said the sort of things I also feel impelled to say. I do not see how I could have done the kind of work mentioned in the citation if I had not been fortunate enough to be associated with creative and enthusiastic groups of colleagues. In my case there were two in particular, one at the University of Pittsburgh, the other at Michigan.

I liked to believe that at Pitt we had in Fred Biondi, Wade Fite, Ed Garjury, Ted Holstein, Fred Kaufman, Don Shemansky, and Ed Zipf the optimum mix of physicists, chemists, and aeronomers to do atmospheric science. That was until I went to Michigan and found myself with a different but equally stimulating group of colleagues: Jim Anderson, Sushil Atreya, George Carignan, Ralph Cicerone, Shaw Liu, Paul Haye, Bill Kuhn, Andy Nagy, Bill Sharp, Doug and Marcia Torr, and Jim Walker. You will have to admit that I have had a lot of firepower to support me.

In addition to these immediate colleagues there are several others with whom I have had the privilege of close collaboration over a period of almost 30 years, and they have been of inestimable value to me. No one among those I have already mentioned has been closer to me as coworker and friend than Jacques Blamont, Bill Fastie, Bill Hanson, Don Hunten, and Mike McElroy. Each of these knows the nature and significance of our various interactions. And it is a very special pleasure for me to be on the same program as this year's Bowie Medalist, Herb Friedman.

As all academics would suspect, much of my best work has really been done by my students and research associates. I have had some outstanding ones: Jim Anderson, Sushil Atreya, George Doschek, Bruce Guenther, Jim Kasting, Shaw Liu, John McAfee, Bob Meier, Ian Stewart, Doug Strickland, Gary Thomas, Andy Watson—to drop only a few names.

With associates like these it would have been hard for me to avoid being involved in the kind of work that you are recognizing here tonight. My hope is that future candidates for the Fleming medal will have the chance to enjoy working with colleagues of this same caliber and will have an opportunity to explore the solar system comparable to the one I have had.

Thomas M. Donahue

AGU FALL MEETING

In the City by the Bay

San Francisco Dec. 7–11

Abstract Deadline:
September 16, 1981

Meetings

International Mars Colloquium

The Third International Mars Colloquium, hosted by the Jet Propulsion Laboratory and the California Institute of Technology, will be held August 31 through September 2 at the Caltech campus.

The colloquium will cover the information collected for more than 4 years at Mars and will allow scientists to compare their research. Cosponsors of the colloquium are NASA, the Lunar and Planetary Institute, and the Division of Planetary Sciences of the American Astronomical Society.

The first Mars colloquium was held in 1973, after the Mariner 9 mission to orbit Mars in 1971 and 1972. The second was held in 1979, after Viking had operated for about 3 years on Mars.

For information on the scientific content of the colloquium, contact Conway Snyder, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Mail Stop 230-111C, Pasadena, CA 91109 (telephone: 213-354-7976).

Working Conference on Current Measurement

The Current Measurement Technology Committee of the Council on Oceanic Engineering, the Institute of Electrical and Electronics Engineers (IEEE), will sponsor the Second Working Conference on Current Measurement on January 19–21, 1982, at the Hilton Head Inn & Sea Pines Plantation at Hilton Head Island in South Carolina. The conference is the follow-up to the 1978 Delaware Conference on Current Measurement.

The theme will be 'Quality of Measurements—How Can I Collect Data of Sufficient Certainty to Satisfy My Needs?' The conference will feature a manufacturers panel.

To obtain registration information and a conference agenda, contact William E. Woodward, NOAA, Office of Ocean Technology and Engineering Services, 6010 Executive Boulevard, Rockville, MD 20852 (telephone: 301-443-8444).

Rock Mechanics Symposium

A call for papers has been issued for the 23rd U.S. Symposium on Rock Mechanics, to be held August 25–27, 1982, at the University of California at Berkeley.

The theme of the symposium is 'Issues in Rock Mechanics.' Topics to be discussed include in-situ stress measurement; geological stress determination; mechanical, thermal, and hydraulic properties of rock masses; rock mass exploration; rock fracture mechanics; brittle-ductile transition; deformation mechanisms and texture development; scaling of test data; numerical modeling; instrumentation; statistics in rock mechanics; rock reinforcement; energy recovery and storage; dynamic rock mechanisms and related applications; creep mechanisms; and large-scale field experiments.

Prospective authors are invited to submit abstracts of not more than three to four typed, double-spaced pages (1000 to 1200 words plus one or two figures) by January 29 to Organizing Committee, 23rd Rock Mechanics Symposium, c/o Richard E. Goodman, Department of Civil Engineering, 440 Davis Hall, University of California, Berkeley, CA 94720. Authors will be notified by March 1; the deadline for completed papers is May 1.

To receive a final symposium program with registration information, write to Continuing Education in Engineering, University of California Extension, 2223 Fulton St., Berkeley, CA 94720. The final program will be available in May.

The meeting is sponsored by the U.S. National Committee for Rock Mechanics, the International Society for Rock Mechanics, and the University of California.

IES '81—Effect of the Ionosphere on Radiowave Systems

A symposium entitled 'Effect of the Ionosphere on Radiowave Systems' was held on April 14–16, 1981, at the Ramada Inn, Old Town, Alexandria, Virginia. Over 250 participants from government, private industry, and academia were in attendance at the symposium, which was organized by John M. Goodman of the Naval Research Laboratory and Jules Aarons of the Air Force Geophysics Laboratory and was sponsored by the Office of Naval Research, NRL, and AFGL. The purpose of the symposium, as in the two previous IES conferences, held in 1975 and 1978, was to improve the information transfer between system architects, managers, and designers on the one hand and ionospheric physicists and propagation specialists on the other hand. Although the military (DoD) interest associated with various topics presented at the conference was transparent, the commercial and scientific research areas were also in evidence.

The conference was keynoted by Hans Mark, who, fresh from his participation in the launch of the space shuttle, provided the attendees with his perceptions of the future direction of the space program. A special address was presented by J. N. Birch that highlighted the ionospheric research needs of present and future-planned DoD systems. A banquet, held on the evening of April 15, had as its guest speaker J. A. Van Allen, who discussed 'The Magnetospheres of the Planets.'

The conference itself covered various topics of current interest to the ionospheric research community. Sessions topics included 'Ionospheric Modification,' chaired by J. M. Goodman; 'General Reviews and Total Electron Content,' chaired by J. Kelso; 'Equatorial Scintillation Studies,' chaired by K. Davies; 'High-Latitude Scintillation,' chaired by E. Fremouw; 'Sub-HF Propagation and System Effects,' chaired by G. Lane; 'Ionospheric and Propagation Models,' chaired by J. Aarons; and 'Future Plans and Programs,' chaired by S. Ossakow.

One of the areas of interest emphasized in the conference was ionospheric modification. There were 13 papers presented on this topic alone. The papers dealt with rocket plume effects, chemical releases, optical diagnostics, in-situ active experiments, ionospheric heating and its various manifestations, and possible applications of modification to the communication research community.

Several review papers were presented at the conference, including 'Recent Developments in Artificial Ionospheric Heating,' by C. M. Rush; 'Ionospheric Predictions—A Review of the State of the Art,' by K. Davies; 'New Forecasting Methods of the Intensity and Time Development of Geomagnetic and Ionospheric Storms,' by S. I. Akasofu; 'Recent High-Latitude Improvements in a Computer-Based Scintillation Model,' by E. J. Fremouw and J. M. Lansinger; and 'Effects of the Ionosphere on HF Radar Propagation,' by D. B. Trizna and J. M. Headrick.

A preprint document containing 75 papers is now available. Those interested should contact F. D. Clarke, IES '81 Program Coordinator, Code 4181A, Naval Research Laboratory, Washington, D.C. 20375.

This meeting report was prepared by John M. Goodman, Chief, Ionospheric Effects Branch, Space Science Division, Naval Research Laboratory, Washington, D.C.

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The Thermal and Dynamic State of the Earth*

Glyn M. Jones

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Introduction

The thermal state of the earth's interior is a topic of fundamental importance in many branches of geophysics. Investigations ranging from the dynamo theory of the origin of the earth's magnetic field to the driving mechanism for plate motions are all ultimately concerned with the question of how heat is transferred in various regions of the earth and what are the resulting flow patterns and temperature at depth.

Present ideas on this problem are in a state of flux. New insights are being brought to bear on old problems, and additional questions are being raised. For example, analysis of postglacial rebound data from the Canadian shield has led to the interpretation that the effective viscosity of the lower mantle may not be significantly larger than that of the upper mantle, as had been previously thought. As a consequence, there has been a revival of interest in mantle-wide convection as the dominant mode of heat transfer within the mantle. A major uncertainty which remains, however, is whether mantle-wide convection would consist of a single flow system extending from the base of the lithosphere to the core-mantle boundary or whether there are, for example, separate flow systems in the upper and lower mantle, separated by a thermal boundary layer at about the depth of the 670-km phase transition.

The possibility of convection throughout the mantle has, in turn, influenced ideas about the thermal evolution of the earth. Convection is an efficient means of transferring heat, and the earth's thermal evolution would necessarily have been very different if throughout its history convection had been mantle-wide rather than confined to the upper mantle. In the former case, cooling of the core becomes a significant factor, with important implications for the growth of the inner core and maintenance of the geomagnetic dynamo.

In order to address these and other major questions that have been raised in recent years about the thermal state of the earth's interior, an international conference devoted to 'Mathematical Problems of the Thermal and Dynamic State of the Earth' was held from July 28–August 3, 1980, at the Lake Arrowhead Conference Center of the University of California, Los Angeles. The conference attracted 85 scientists including 15 graduate students, from 12 countries. The conference sessions were grouped under the following main headings:

1. Thermodynamics and Dynamics of the Core
2. Heat Transfer in the Mantle
3. Observational Constraints on the Earth's Thermal Regime
4. Thermal Evolution of the Earth and Terrestrial Planets

A wide variety of opinions and approaches to these topics were represented at the conference, and most of the sessions were marked by lively discussion. The following report emphasizes the main topics which were discussed. Additional details can be obtained from the full conference report, including abstracts. A limited number of bound copies of the report are available and can be obtained by writing to Glyn Jones, Dept. of Geophysics, Texas A&M University, College Station, Texas 77843.

Thermodynamics and Dynamics of the Core

Estimates of present temperatures in the core are of crucial importance in evaluating current theories of the state of the core and its thermal evolution. Using the Lindemann theory of melting, Stacey finds that the melting temperature of pure iron at the pressure (3.2 Mbar) of the inner-core boundary is 6420°K. The effect of alloying lighter material (S or O?) is uncertain since the appropriate phase relationships are unknown at these pressures. Based upon the extrapolation from lower pressures of the behavior of the Fe-FeS eutectic [*Usselman*, 1975*a*, *b*], the temperature at the inner-core boundary may be as low as 4200°K. This is probably a lower bound, however, since the mean composition of the core, if sulfur is indeed the lighter element present, may lie closer to the Fe end member than to the eutectic composition [*Ahrens*, 1979]. Determination of the phase relationships for likely core materials at the appropriate pressures would help to remove a great deal of the present uncertainty. Using the low figure for the temperature at the inner-core boundary, adiabatic extrapolation to the core-mantle boundary gives a temperature there of 2900°K. Using a completely different approach which utilizes a generalized form of the Mie-Gruneisen equation of state [*Brennan and Stacey*, 1979] and earth model data, Stacey calculates a perhaps more reasonable temperature of 3770°K at the core-mantle boundary.

Since the outer core is known to be a metallic liquid, it would seem logical to attempt to understand its properties by using liquid-state rather than solid-state theory. Stevenson outlined recent theoretical approaches to this problem. Encouraging results have already been obtained by using a 'hard-sphere' model of liquid structure [*Stevenson*, 1980], including an independent derivation of Lindemann's law of melting under the condition that the pair distribution function preserves its shape along the melting curve. More realistic models of the pair potential are needed, however, to make further progress [*Boschi et al.*, 1979]. Because of the difficulty in specifying on purely theoretical grounds the contribution of itinerant electron states to the internal energy budget, it appears that the most profitable future approach will include a combination of empirical and numerical (e.g., Monte Carlo) techniques.

The question of energy sources for the geomagnetic dynamo is also central to any discussion of the thermal regime of the core. Maintenance of the geomagnetic field against ohmic dissipation requires a supply of magnetic energy at the rate of about 10^{11} W for a toroidal field of a few hundred Gauss. This energy is supplied by the work done against the Lorentz force by fluid motions in the outer core. The actual power requirement for dynamo action therefore depends upon how efficiently fluid motions can be maintained in the outer core. Gubbins reviewed the possibilities.

Precessional torques, once considered a viable source of energy for the magnetic field, have been shown to be dynamically inefficient [*Rochester et al.*, 1975]. The most plausible other energy sources appear to be the possible presence of K^{40} in the outer core and/or slow cooling of the core. The latter mechanism involves differentiation at the inner-core boundary of outer-core material into a heavy solid fraction which sinks to enlarge the inner core, leaving a lighter liquid residue that rises through the outer core and may induce motions there sufficient to maintain the dynamo.

This mechanism, originally proposed by *Braginsky* [1963], is favored by Gubbins on the grounds of its apparently greater efficiency compared to thermal convection driven by internal energy sources. Fearn and Loper discussed the process in more detail and concluded that, with some modifications to Braginsky's original hypothesis, the mechanism is a viable one for maintaining the magnetic field [*Fearn and Loper*, 1981]. Loper raised the interesting possibility that the inner core may actually grow through the formation of dendrites above the inner-core boundary, a phenomenon which has been directly observed in the solidification of metal castings subject to unidirectional cooling.

Thermal convection in the outer core driven by distributed heat sources cannot, however, be dismissed on the basis of efficiency arguments alone [*Verhoogen*, 1980], and it appears that other arguments will have to be made for preferring one mechanism over the other. The theoretical calculations of Bukowinski, for instance, suggest that at sufficiently high pressures the heavy alkali metals may undergo a change in electronic configuration which would considerably alter their chemical properties [*Bukowinski and Hauser*, 1980]. This may enhance the case for incorporation of radioactive elements into the core during the early evolution of the earth.

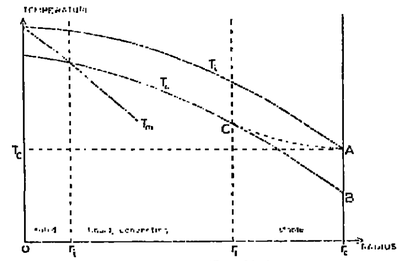

Fig. 1. Possible temperature profile within the core, leading to the formation of a stable region at the top of the core (from paper presented by D. Gubbins); T_m is the melting temperature, T_i the initial (adiabatic) temperature, and T_c the present temperature. If the mantle temperature is fixed at T_c, the core will still continue to cool and will eventually become sub-adiabatic somewhere. Here the region between C and A is assumed stable, with the temperature obeying the conduction equation and matching the adiabat at C.

An argument that is relevant here is the question of how much heat is flowing across the core-mantle boundary. This is linked to the efficiency of heat transfer through the mantle, which is discussed further below. Gubbins suggests, however, that if the necessary heat cannot be extracted from the core fast enough, this may lead to the development of a stably stratified region at the top of the outer core within which radial motions would be inhibited (Figure 1). Whaler pointed out that under such circumstances, the frozen-flux induction equation predicts that local extrema of the poloidal component B_r of the magnetic field should coincide with points of zero time-rate-of-change of B_r. Downward continuation of the 1965 IGRF to the core-mantle boundary and consideration of its secular variation suggests that this condition is satisfied, thereby supporting the concept of a stratified layer immediately below the core-mantle boundary. Benton, using a similar approach, argued, however, that the correlation depends critically upon the truncation level assumed for the reference field and that, at best, it may only be possible to place bounds upon the magnitude of the radial velocity component near the top of the core, which may or may not prove subsequently useful in modeling the dynamics of the core [*Benton et al.*, 1979].

Exactly how much heat must be extracted from the core in order to maintain the geomagnetic dynamo depends upon which particular energy source is assumed and the amount of magnetic energy required. For thermal convection in the outer core driven by distributed heat sources a lower bound is given by the amount of heat conducted along the adiabat ($\sim 5 \times 10^{12}$ W), whereas the upper bound depends on how large a magnetic field needs to be maintained. For the case of a dynamo driven by differentiation of heavy and light material at the inner-core boundary, however, it is possible that the heat output from the core could be less than 5×10^{12} W [*Loper*, 1978; *Gubbins et al.*, 1979]. In this case, however, the efficiency of dynamo action is impaired by the amount of additional energy that is required to drive convection in the presence of a stabilizing thermal gradient. In order to place bounds upon the range of possible models, more detailed understanding of dynamo action in the core is therefore required.

Busse described some interesting results obtained through the use of numerical integration of the full set of MHD equations in a rotating spherical shell. The method is iterative, involving perturbations upon successively more complicated initial states [*Busse*, 1979; *Cuong and Busse*, 1981]. The initial velocity field assumed consists of cylindrical convection columns parallel to the rotation axis superimposed on a differential rotation. Although no complete solutions have yet been obtained, initial results suggest that in the absence of differential rotation, solutions of dipolar and quadrupolar symmetry for the poloidal component of the magnetic field are almost equally preferred. Thus differential rotation in the outer core may be required to suppress solutions of quadrupolar symmetry in favor of the dipolar field which is actually observed. If correct, this result would appear to favor the existence of a moderate to large toroidal magnetic field in the outer core.

Heat Transfer in the Mantle

The conclusion, derived from postglacial rebound studies of the Canadian shield, that the viscosity of the lower mantle may not be significantly greater than that of the upper mantle has had a profound impact upon recent studies of the transfer of heat through the mantle. The implications of deep mantle convection therefore formed the focus for a number of papers presented at the conference.

Peltier reviewed the evidence on deep mantle viscosity. Inversion of relative sea level data and free-air gravity anomalies over the Canadian shield, assuming a mantle with no large compositional gradients, constrains the effective viscosity of the lower mantle to lie between 10^{22} poise and 3×10^{22} poise, with the lower limit being preferred

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Cover. A model for the breakup of Gondwana. Subduction along the western coast induces a large-aspect-ratio convection cell beneath the continent, which may create stresses sufficient to cause a breakup. From paper presented by C. Froidevaux and H. C. Nataf at the Lake Arrowhead conference on Mathematical Problems of the Thermal and Dynamic State of the Earth. (See article, p. 609, this issue.)

[*Peltier*, 1981]. The implication of this result is that, given reasonable estimates of heat sources in the lower mantle and heat flow across the core-mantle boundary, the lower mantle is very likely to be convecting everywhere, with an average temperature gradient close to an adiabatic value, except in thermal boundary layers at the base of the mantle and, possibly, at the top of the lower mantle, within which temperature gradients would be much steeper. The concept of a thermal boundary layer at the base of the mantle appears to be supported by several independent lines of evidence.

It has long been recognized that within the lower 100–200 km of the mantle (region D"), seismic velocity gradients are anomalous. From a detailed analysis of the attenuation of diffracted *P* and *S* waves in the shadow zone, Doornbos concludes that the data require a low velocity zone for *S*, and possibly also for *P*, within the lower 100 km of the mantle [*Doornbos and Mondt*, 1979*a*, *b*]. The data are consistent with a temperature drop across D" of approximately 1000°. Independent estimates of temperatures in the lower mantle, based upon earth model data, also appear to require large thermal gradients in this region in order to reconcile temperature values obtained above D" with the higher temperature values inferred at the top of the core. The most reasonable explanation for these results is that they reflect the existence of a thermal boundary layer above the core-mantle boundary that is maintained by convection in the lower mantle. Fluff reported, however, that analysis of short-period *P* waves that grazed the core in a restricted region beneath the north pole does not support the concept of a simple low-velocity zone at the base of the mantle. This may mean that either D" is laterally heterogeneous or else the structure of D" is more complicated than hitherto suspected.

The question of whether convection in a mantle of uniform viscosity would consist of a single flow system or separate flow systems at different depths was discussed at length. The most significant barrier to whole-mantle convection under this condition would appear to be a difference in bulk composition between the upper and lower mantle. A minor increase in iron content below the depth of the 670-km phase transition might, for example, be sufficient to restrict thermal convection to the upper and lower mantles separately.

The report by Bell of ultra-high-pressure laboratory studies of the nature of the 670-km phase transition was therefore received with great interest. Bell and his coworkers [*Bell et al.* 1979; *Yagi et al.*, 1979] have found that at a pressure of 235 kbar (670 km), spinel with composition $(Fe_{90}Fe_{10})_2$ inverts to perovskite $[(Mg,Fe)SiO_3]$ with $X_{Fe} = 0.02$ (where $X_{Fe} = Fe/(Fe + Mg)$ in moles) plus magnesiowustite $[(Mg,Fe)O]$ with $X_{Fe} = 0.2$. The partitioning of Fe preferentially into the oxide phase rather than the more dense perovskite phase results in a mixture with an overall density very close to the PEM model of *Dziewonski et al.* [1975] below 670 km. There are indications that the resulting mixture may be stable all the way to the core-mantle boundary. These results do not therefore appear to require a change in bulk chemistry across the 670-km transition, although uncertainty about the exact composition of the upper mantle means that this possibility cannot be completely ruled out. Further experiments on the thermodynamic properties of this phase transition will be of great importance in determining the thermal gradients to be expected in this region for the opposing cases of convection through the phase transition or thermal boundary layers above and below the transition level. Olson finds that temperature jumps of up to 2000° can occur across internal boundary layers in models with double-layer circulation. In contrast, single-layer circulation in a spherical shell of uniform properties results in a nearly uniform, averaged internal temperature [*Zebib et al.*, 1980]. If it should prove possible to determine the properties of the phase transition with sufficient accuracy, then seismological data might be used to discriminate between the possible cases.

Other types of data that may be relevant to the question of single- versus multiple-layered convection in the mantle include the distribution and energy release in deep earthquakes and differences between the isotopic composition of continental rocks and oceanic basalts.

Deep earthquakes beneath some trenches show a sharp burst of activity just above a depth of 670 km, followed by an abrupt cutoff in activity below this depth. Although the exact cause of deep earthquakes is uncertain, this observation does suggest that downgoing slabs experience a resistance to penetration through the 670-km phase transition [*Richter*, 1979]. This may be caused by a change in either the mechanical properties or the chemical composition of the mantle at this depth.

The concept of a chemically layered mantle has also been suggested on the basis of isotopic studies of continental rocks and oceanic basalts (e.g., *Wasserburg and DePaolo*, 1979]. These studies suggest that continental crust and midocean ridge basalts (MORB's) are enriched and depleted, respectively, in certain large-ion elements relative to chondrites. Assuming that the continents have evolved with time from a primitive mantle of chondritic composition, leaving a depleted reservoir which is the present source of MORB's, it is possible to estimate the volume of material that must have been involved to produce the relative isotopic abundances observed. Richter and D. Anderson reported that such calculations come out with a figure of about one-third of the volume of the present mantle, equivalent to the upper mantle above the 670-km transition zone. The implication of this result is that the upper and lower mantles may have been isolated chemically for 1 b.y. or more, with the lower mantle remaining primitive and, presumably, retaining most of its original radioactive heat sources.

A variety of models were proposed to explain how this differentiation may have occurred (see discussion below). It is uncertain how these interpretations will hold up as more data are collected, but if the concept of separate chemical reservoirs in the upper and lower mantle is subsequently confirmed, it would obviously have major implications for flow patterns in the mantle and in the distribution of heat sources. Under these circumstances the implications of postglacial rebound data for the viscosity of the lower mantle may have to be reinterpreted, since present interpretations assume that a continuous flow system extends down to the core-mantle boundary.

Still another approach to the question of the scale of flow in the mantle is through the use of boundary layer models that attempt to assess the influence of various modes of mantle convection upon observed surface variables and temperatures in the core. Using the mean-field approximation to express the horizontal structure of the flow in terms of a single spherical harmonic, Olson finds that in the limit of asymptotically large Rayleigh number the simplest model which gives reasonable values for surface heat flux, angular plate velocities, and core temperatures consists of a single circulating layer that is partially heated by the core. The possible importance of core heat was further emphasized by Jarvis, who reported that models involving mantle-wide convection driven by a combination of about 80% heat flux from below and 20% internal heat predict a flattening of surface topography with age similar to that observed in the oceans [*Jarvis and Peltier*, 1980].

The direct applicability of these results to the mantle is, however, uncertain, since the effects of a realistic mantle rheology have yet to be incorporated. Hughes pointed out that the nonlinear dependence of strain rate on temperature and stress in mantle materials is likely to lead to complicated patterns of flow quite unlike those observed in simple Newtonian fluids. The flow may also be fundamentally time dependent if two or more interdependent relaxation mechanisms operate [*Gangi*, 1981]. On the other hand, Tozer argued that within a fluid with internal heat sources in which the viscosity is a strong function of temperature the internal temperature and viscosity may be constrained within fairly narrow bounds. If the internal temperature is originally low, the viscosity will be high and the internal temperature will rise because the heat generated by the heat sources cannot be removed efficiently. As the temperature rises, however, the viscosity will decrease, convection will become more vigorous, and the temperature will decrease again. Thus, on the average, a quasi steady state may prevail in which the internal temperature and viscosity will be approximately constant. Under these circumstances, the main differences between temperature-dependent and constant viscosity flows may occur predominantly in the structure of the boundary layers.

In this vein, Ivins reported that the heat transported through a fluid shell with temperature-dependent viscosity is reduced in comparison with the constant viscosity case because of the formation of a high-viscosity boundary layer at the surface, through which heat is lost mainly by conduction. A related effect of the viscosity variation is that the horizontal wavelengths of flow which maximize the heat transport are smaller than the values predicted via the use of constant viscosity results. This result assumes significance because of Daly's demonstration that at high Rayleigh numbers the mean heat flow across the upper boundary layer of a variable-viscosity system is a sensitive function of the dominant wavelength of the interior flow (Figure 2). It is apparent from these results that while the temperature dependence of viscosity in mantle materials may well account for the apparent uniformity of viscosity with depth in the mantle, there are many details about the structure of likely mantle flows that remain to be resolved.

Since the lithosphere forms the cold upper boundary layer of mantle flow, is it possible to use observations of plate velocities as a constraining factor on mantle rheology and the scale of convection? Hager described recent numerical models designed to address this point. The problem is complicated by the fact that it is not known whether plates are driven by mantle flow beneath the plates or density gradients within the plates themselves. Adopting the latter view, Hager finds that it is possible to construct a self-consistent force balance for each plate, with a range of viscosity models and aspect ratios for the flow. Independent estimates of one variable would, however, allow the other to be constrained within useful bounds.

A more empirical approach to the question of flow and stress in the mantle was presented by Anderson and Minster. In their method, they first construct a theoretical model of the dislocation structure within mineral subgrains as a function of temperature and stress [*Anderson and Minster*, 1981; *Minster and Anderson*, 1981]. The model is sufficiently broad to encompass both seismic wave attenuation and steady state creep. Laboratory creep data on olivine is then used to restrict the class of theoretical models. Finally, the observed frequency dependence of Q in the mantle is used to place bounds on the temperature and stress state

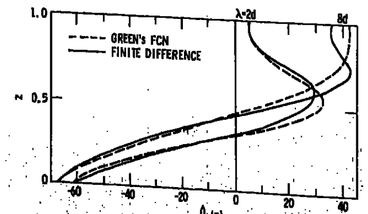

Fig. 2. Velocity profiles for variable-viscosity convection in a box of aspect ratio λ/d (from paper by S. Daly). The velocity structure in the upper boundary layer is a strong function of the dominant wavelength of the interior flow. This results in more efficient cooling and lower internal temperatures as the dominant wavelength increases.

of the mantle at different depths. Lateral variations in Q can, in principle, be used to infer lateral changes in stress and temperature. Initial results, using this method, are generally consistent with other estimates of temperatures in the mantle, and future results will be awaited with interest.

Turning to more detailed models of thermal processes in the upper mantle, a number of authors dealt with questions of lateral heterogeneity and stability in upper mantle thermal systems. These investigations ranged in scale from analysis of the stability of the lithospheric thermal boundary layer beneath continents and oceans to Soret convection in magma chambers and the ascent of magma. Melosh argued the case for asthenospheric shear heating beneath continents, and Froidevaux discussed the possible effect of a cold, downgoing slab upon the aspect ratio of convection under a neighboring continent [*Rabinowitz et al.*, 1980].

These topics illustrate the types of problems that need to be addressed if progress is to be made in understanding the complex thermal structure of the upper mantle. To some extent, the ability to address these types of problems in a systematic way is limited by the speed and internal structure of present computing systems. It therefore appears likely that recent revolutionary developments in computer architecture (e.g., parallel processing) and improvements in numerical techniques [*Woldt and Neugebauer*, 1980; *Koplitzke*, 1979] will have a significant impact upon the range of problems that can be feasibly studied in the future.

Observational Constraints on the Earth's Thermal Regime

Measurements of the conductive heat flux crossing the earth's surface and its variation with the age of surface features have provided important constraints on models of plate production and the distribution of radioactivity within the continents. If the transfer of heat within the earth is rapid, as would be the case if some form of mantle-wide convection exists, then the present mean heat loss of the earth also places a fundamental constraint on the total rate of heat production within the earth.

As pointed out by Lister, estimates of the mean heat loss of the earth have risen sharply in recent years because of the discovery that hydrothermal circulation at ridge crests may play a major role in removing heat from young oceanic crust [*Lister*, 1980]. Heat flow measurements over ridges fall substantially below estimates based upon theoretical models of a cooling plate [*Sclater et al.*, 1980]. The discrepancy can be attributed to the penetration of cold seawater to a depth of several kilometers along fractures in young ocean crust. This cools the material and results in conductive thermal gradients that are too low. Present estimates of the total heat loss of the earth, taking hydrothermal circulation into account, amount to about 4.2×10^{13} W (10^{13} cal/s), a substantial increase over previous estimates

Ida presented, however, a different interpretation of the heat flow data over ocean ridges. According to his model, the low heat flow values measured in these regions result not from hydrothermal circulation but because of small-scale convection in the asthenosphere beneath the ridge, which transfers heat laterally between the axis and flanks of the ridge. This results in a more even distribution of heat flow values at the surface than predicted by simple cooling models.

The interpretation of heat flow measurements on the continents was discussed at length. Most workers are in agreement that the statistical trend of decreasing heat flow on the continents with increasing basement age is real, but there is disagreement as to how this trend should be interpreted. The controversy centers around whether or not the measurements require a substantially thicker lithosphere beneath continental shields than beneath old ocean basins; a question which is of importance with regard to the viscous coupling of continents to flow beneath the plates.

Interpretation is complicated by the uncertain effects of processes such as plutonism, continent-continent collision, erosion, water circulation within the crust, etc., which produce a large scatter in the measured heat flow values. The concept of a 'heat flow province,' within which surface heat flow and radiogenic heat production are found to be linearly related, has, however, led to the recognition that a large part of the scatter can be attributed to variations in near-surface heat sources. In regions where a satisfactory linear relation can be obtained, the reduced heat flow value Q_0, interpreted as representing the nonradiogenic contribution to the surface heat flow, therefore appears to be a more useful basis for comparison than the surface heat flow values themselves.

For North America, Q_0 values appear to follow an initial $(age)^{-1/2}$ decay out to 200 m.y. or so, after which they flatten out to a constant value of 25–30 mW/m² (0.6–0.7 μcal/cm²s) (Figure 3). The figure of 200 m.y. is sufficiently close to the inferred value of 120 m.y. for flattening of the oceanic heat flow curve to suggest that the equilibrium thickness of continental lithosphere beneath North America may be similar to that for old oceanic lithosphere.

This result differs from previous interpretations that were based upon the variation of surface heat flow values alone and which appear to suggest an equilibrium lithosphere thickness beneath continents of 300 km or more [*Pollack and Chapman*, 1977]. England proposed that the discrepancy can be resolved in favor of a thinner continental lithosphere if erosion of the continents is taken into account. According to his model, the surface heat flow observations may be satisfied if erosion of 20–30 km of continental crust occurs in 100–200 m.y., with a lithosphere that is less than 150 km thick [*England and Richardson*, 1981]. The limiting mechanism for this much erosion may be the thickening of the continental crust at a compressive plate boundary. DePaolo pointed out, however, that the vertical distribution of heat-producing elements within continental crust is likely to vary with the time of formation of the crust, interpretation based upon the assumption that the bulk of radio-

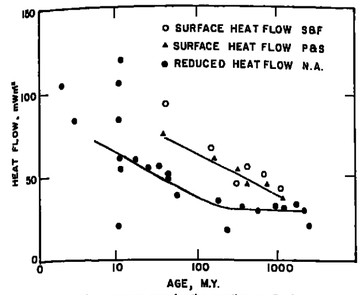

Fig. 3. Heat flow versus age for the continents. Surface heat flow data from *Polyak and Smirnov* [1968] and *Sclater and Francheteau* [1970]. Reduced heat flow values Q_0 compiled for North America. From paper by D. D. Blackwell and S. Chockalingam.

active heat sources occur everywhere at shallow depths may therefore be substantially in error. Rao further emphasized the problems involved in using data from different regions to attempt to define a universal heat flow-age relation for the continents analogous to that obtained in the oceans. The other participants agreed that it is important to understand the effect of local processes before attempting to isolate broader trends that may reflect deeper processes.

A great deal of uncertainty relating to lithosphere structure and mantle convection would be eliminated by independent estimates of the temperature at depth. Huestis discussed the problem of inverting heat flow data to infer steady state subsurface temperatures by using a Backus-Gilbert formalism [*Huestis*, 1979, 1980]. In another approach to the determination of the shallow thermal regime, the current state of the art in geothermometry was reviewed by *Mercier* [1980].

Direct determination of temperatures in the lower mantle, although of obvious importance to many of the topics discussed at the conference, is hampered because of uncertainty about the detailed composition and physical properties of this region. Graham has performed a careful analysis of the constraints imposed by earth model data and finds that, for a range of plausible lower-mantle models, adiabatic conditions and temperatures of 2600–2900°K near the base of the mantle are compatible with model B1 of *Jordan and Anderson* [1974]. Similar results were obtained by O. Anderson, who used a different method [*Anderson*, 1980]. As mentioned before, these estimates of temperatures above the core-mantle boundary are substantially lower than most recent estimates of temperatures at the top of the core and therefore, if correct, appear to provide support for the concept of a thermal boundary layer at the base of the mantle.

Turning to the question of how lateral temperature anomalies in the mantle might be detected through the use of seismological data, Knopoff reported that ultra-long-period Rayleigh waves that have travelled along the East Pacific Rise have phase velocities which are significantly lower than the global averages. Inversion of the dispersion data leads to two alternative models for the deep velocity structure beneath this region: one model in which sharp velocity minima are centered around 100 and 450 km depth; the other model with smaller velocity perturbations extending down to 650 km and possibly deeper. The latter model is compatible with the existence of deep flow beneath the East Pacific Rise, possibly extending into the lower mantle.

Precision mapping of the shape of the oceanic geoid by using satellite radar altimetry is another tool which has recently become available to geophysicists interested in the thermal state of the earth. Runcorn reviewed historical interpretations of the geoid and pointed out the important role played by the lithosphere in controlling the sign of the geoid anomaly to be expected over upwelling and downwelling flows. This point was further explained by Parsons. Numerical experiments have shown that the relationship between geoid anomalies and surface deformation produced by convection is principally determined by the wavelength of the feature relative to the depth of the convecting layer and assumptions about the way in which the upper and lower boundaries deform. In applying these results to the mantle, only features with wavelengths greater than 400 km should be considered since shorter-wavelength features reflect the properties of the overlying elastic plate. Preliminary results obtained from analysis of long-wavelength satellite altimetry data and seafloor topography in the Pacific suggest the existence of a complex pattern of flow in the mantle beneath this region. Jones reported that there appears to be a systematic inverse correlation between the amplitude of long-wavelength geoid anomalies crossing trench-island arc systems and the age of the associated back-arc basin (Figure 4). This result suggests a link between the deep structure of subduction zones and tectonic processes at shallow depths. Finally, Kaula has analyzed, on a global basis, variations in surface plate velocity, gravity, topography, and heat flow. The spectra of these quantities provide constraints on the depth variation of physical parameters related to convection [*Kaula*, 1980]. Kaula finds that the spectra of gravity variations and plate velocities lead to an estimate of 4×10^{22} poise for the effective viscosity of the lithosphere. This low estimate is weighted heavily towards regions of high strain rate and large gravity anomalies, i.e., subduction zones, and may therefore physically represent the efficient release of stress in these regions by earthquakes.

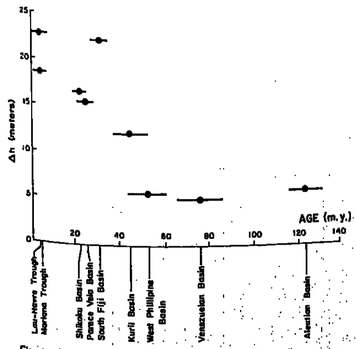

Fig. 4. Averaged geoid height variation crossing various trench-island arc-back arc regions as a function of the inferred age of the back-arc region (from paper by G. Jones); Δh is the difference between $10° \times 10°$ averages of geoid height seaward of the trench and over the associated back-arc region; estimated from the geoid anomaly map of *Brace* [1977]. Age data from *Watanabe et al.* [1977].

Thermal Evolution of the Earth and Terrestrial Planets

The realization that convection may be the dominant mode of heat transfer all the way from the inner core boundary to the base of the lithosphere has had a major impact upon current models of the earth's thermal evolution.

The basic element of these models is the assumption that on long time scales (100 m.y. or more) the mantle transports heat like a fluid of constant viscosity. The justification for this assumption is the probable 'self-regulating' effect of a strongly temperature-dependent viscosity [*Tozer*, 1972]. Under this assumption it is possible to express the average radial heat transport through the mantle in terms of an empirical Nusselt number—Rayleigh number relation obtained from numerical experiments on convection in constant-viscosity fluids [*McKenzie and Weiss*, 1975]. This approach reduces the full set of equations governing convective heat transport in the earth to a 'parameterized' set which are capable of solution [*Sharpe and Peltier*, 1979].

Although details of the evolutionary history of the earth developed by using this scheme are sensitive to the initial conditions and parameter values assumed, it is found that most reasonable models require heat sources in the core in order to prevent the whole core from freezing during the lifetime of the earth. Stevenson suggested that the release of latent heat at the inner core boundary may be sufficient for this purpose, with no requirement for additional radioactive heat sources in the core. In his models, about 30% of the present surface heat flow is derived from whole-earth cooling, with one-third of this coming from the core.

Peltier warned, however, that caution should be exercised in using the parameterization scheme in its present form, since it is based upon a number of simplifying assumptions which have yet to be rigorously tested. The role played by the lithosphere, for example, which in light of the variable-viscosity results discussed before is likely to be crucial, has yet to be adequately addressed.

Both Hsui and Stevenson stressed the relative importance of size and temperature-dependent viscosity in controlling the thermal evolution of the terrestrial planets. Small planets such as Mercury or Mars would have cooled off quickly from a hot initial state but may still have partially molten cores because the efficiency of convective heat transfer decreases rapidly as the viscosity increases. The small magnetic fields inferred for these planets may therefore be due to either restricted dynamo action at present or to residual crustal fields derived from the time when dynamo action was more vigorous.

The thermal evolution of the earth is intimately linked with its chemical evolution. Geochemistry therefore provides another constraint which thermal evolution models should take into account. The following is a summary, based upon the papers presented at the conference, of the possible sequence of major events associated with the earth's chemical evolution.

The separation of the core may have started even before the initial accretion was complete, if 50% or more of the gravitational energy released by in-falling matter was retained [*Kaula*, 1979]. Simultaneous differentiation and accretion would have subsequently kept the temperature in the protomantle close to the solidus. The separation of core and mantle may have been essentially complete as early as 4.4 Ga (b.y.b.p.).

Early whole-mantle convection would have resulted in partial melting in the upper mantle and differentiation of the crust. The higher thermal gradients present at that time probably prevented the formation of a stable surface layer: the surface tectonic style may instead have been one of vigorous small-scale convection. Anderson believes that the differentiation of less refractory material from a primitive chondritic mantle may have resulted in the formation of an eclogite cumulate which collected above the 670-km discontinuity, thus effectively shutting off whole-mantle convection at an early stage [*Anderson*, 1979]. Subsequently, according to this view, the upper and lower mantle would have evolved separately. Lambert presented a similar two-layer mantle model to account for the unusual isotopic abundances of some rocks on the continents (Figure 5).

O'Connell argued, however, that whole-mantle convection may also be compatible with the apparent existence of separate chemical reservoirs in the mantle. At the present rate of plate production it would require 4 b.y. to circulate the mass of the mantle through a zone 100 km thick beneath the ridges. In contrast, the ridges sweep out an area equal to the earth's surface in only 0.5 b.y. Thus repeated sampling of the upper mantle beneath ridges may lead to a relatively depleted upper mantle, whereas magma sources which tap the lower mantle would be relatively undepleted.

By the close of the Archean (2.8–2.5 Ga), the continental crust had apparently stabilized, indicating that near-surface temperature gradients had decreased significantly. This may have been a time of microscale plate tectonics, characterized by up to 10 times the present rate of plate production. Since that time, local additions to the continents have occurred, resulting in the complex isotopic and trace element patterns which are observed in continental rocks today. The gradual cooling of the outer layers of the earth and the formation of a thick lithosphere may have greatly reduced the subsequent efficiency of heat removal from the interior.

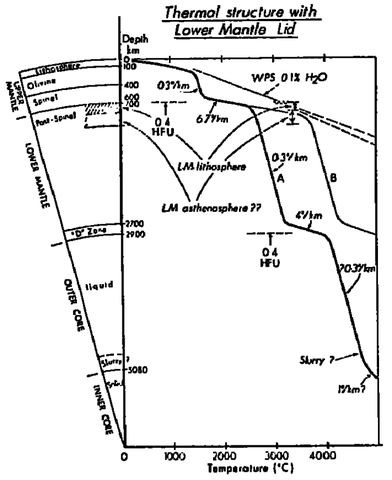

Fig. 5. An average geotherm for the earth with separate upper and lower mantle convection systems proposed by *Lumbert* [1980].

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Glyn Jones was born in Cardiff, S. Wales, and received the B.Sc. degree in physics and mathematics from the University of Wales, Swansea, in 1967. Following graduation, he joined Seismograph Service Ltd. and worked for the next 2 years as an assistant observer on seismic crews in the North Sea and the Middle East. While on leave in Greece, he met his future wife, Pat, who persuaded him to give the New World a try. After two years in New York City, where he was employed by John V. Dinan Associates as an engineering seismologist, monitoring blast vibrations from building excavations, Jones entered the University of California, Berkeley, in 1971 and gained the Ph.D. degree in geophysics in 1976. From 1975 to 1977 he held a postdoctoral position at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, where he worked with Mike Gaposchkin. He joined the geophysics faculty of Texas A&M University in 1977.

Jones' current research interests include numerical modeling of subduction zones and the thermal interaction of the core and the mantle. He is a member of the American Geophysical Union and a Fellow of the Royal Astronomical Society.

News

Environmental Cancer Risks

In a long-awaited report ('Assessment of Technologies for Determining Cancer Risks From the Environment'), the U.S. Office of Technology Assessment (OTA) has evaluated the role of environmental factors in cancer diseases. Environment is interpreted broadly as encompassing anything that interacts with humans, including the natural environment, food, radiation, the workplace, etc. Geologic factors range from geographic location to radiation and specific minerals. The report, however, is based on an inadequate data base in most instances, and its major recommendations are related to the establishment of a national cancer registry to record cancer statistics, as is done for many other diseases. Presently, hard statistics are lacking in the establishment of some association between the cause-effect relationship of most environmental factors and most carcinogens. Of particular interest, but unfortunately based on unreliable data, are the effects of mineral substances such as 'asbestos.' USGS mineralogist Malcolm Ross will review asbestos and its effects on human health in the forthcoming Mineralogical Society of America's Short Course on the Amphiboles (*Reviews in Mineralogy, 9*, in press, 1981).

To understand the problems of evaluating cancer risks from mineral substances is to realize the dilemma of at least four federal government agencies (among others, the Environmental Protection Agency (EPA), the Occupational Safety and Health Agency (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the National Institute of Health (NIH)) and many more private foundations and organizations being involved. Out of the incredibly confused mixture of medical data, legal restrictions, and regulations, however, emerge a few points worth considering. First of all, although the OTA report ascribes as much as 90% of recent cancers (the past two decades) to environmental factors and thus '[The environment) . . . represents cancer causes that are, at least theoretically, modifiable.' The broadness of definition and the lack of hard data result in this meaning only that most cancer (there are 200 diseases included) is not caused by inborn genetic factors. Where mineral substances are involved is what the OTA refers to as 'promotion and synergism,' as follows:

> Cancer causation is thought to involve at least two steps: an early initiation step and a later promotion effect. A single agent may cause both events, or two or more separate agents working in the proper sequence may be necessary. Initiation is generally thought to involve a genetic change in the cell, but that change does not result in a tumor unless a promotion event follows it. The latent period of most cancers—the time between exposure to an initiator and appearance of the disease—is often 20 years or more. This long latent period is the cause of a great deal of apprehension among policymakers, scientists, and the general public because new substances and living habits are continually introduced, and today's harmful exposures may not cause ill effects for years.

Ross points out a number of problems with blaming asbestos as a cancer risk in the U.S. The occurrences of mesothelioma, related to asbestos, are isolated to mines in South Africa and Western Australia where chrysotile is the dominant mineral. In the U.S., asbestos contains little or no chrysotile; chrysotile and anthophyllite are the dominant minerals in U.S. asbestos, and thus asbestos mining in this country does not generally produce a cancer risk. Ross notes that it is the submicron diameters of chrysotile needles that apparently contribute to development of the illness. He defines as risk, fibers greater than 5 μm in length and less than 1 μm in diameter (in concentrations of greater than 1 fiber/cc of air). Other asbestos minerals are greater than 1 μm diameter, and the lung mechanisms can expel them along with other dust and particulate matter. He analyzed the cancer incidence data and concluded that it would be difficult to ascribe more than 1% or so of the cancer cases to an asbestos cause, and even then, he might include other mineral substances.

A more striking incidence seen in the OTA figures is the synergistic or associated factor problem caused by miners smoking tobacco products. Asbestos and, indeed, most other minerals, have little effect as cancer risks in the ventilated (low-to-medium dust content) air found in U.S. mines—unless an individual smokes. According to OTA, 'The multiplicative effects of cigarette smoking and exposure to asbestos . . . [is a] well-known example of synergism.' Ross believes that nonsmoking should be a national requirement for those employed in mining or other industries with dusty surroundings. The costs in terms of human health and in terms of money are immense.—*PMB*

NRC: Wait on SPS Research

A National Research Council committee recommends that funds not be allocated during this decade for research and development of a satellite power system (SPS). Instead, NASA should monitor relevant technical developments and report periodically to Congress.

Cost is the major obstacle to pursuing SPS, according to the Committee on Satellite Power Systems. Earlier estimates of $1.3 trillion are 2½ times too low, even in the most optimistic view, according to the committee. Better energy R&D prospects—technologically and economically—include breeder reactors, advanced coal-burning technologies, and solar power from terrestrial photovoltaic cells. The committee also felt that, among other problems, SPS could interfere with terrestrial radio communications and with optical and radio astronomy.

SPS, as described in a 3-year NASA/Department of Energy report that was completed last year, would use 60 satellites circling earth in geosynchronous orbit. Each satellite would weigh 56,000 tons and have an area equivalent to Manhattan Island. The whole system would beam solar energy to earth to deliver 300 billion watts of electricity to power grids by 2030.

In its review of the NASA/DOE study, the NRC committee said that the final report, though chock full of 'information useful for policy-making as well as other purposes,' adopted 'an optimistic rather than a pragmatic' view of technical performance, cost estimates, and deployment schedules. Construction of the mammoth satellites, for example, would require vehicles with 13 times the cargo capacity of the present space shuttle to be launched more than once a day for 30 years. DOE maintains that its report was neutral, not optimistic, in balancing technical feasibility and cost.

The Committee on Satellite Power Systems, a part of the Environmental Studies Board, was chaired by Dale R. Corson, president emeritus of Cornell University.—*BTR*

Geophysicists

Roger W. Greensfelder joined the consulting firm of Converse Ward Davis Dixon as a principal seismologist in the firm's San Francisco office. He is responsible for research and consultation on various aspects of seismotectonics and engineering seismology.

Greensfelder

Classified

EOS offers classified space for Positions Available, Positions Wanted, and Services, Supplies, Courses, and Announcements. There are no discounts or commissions on classified ads. Any type that is not publisher's choice is charged for at display rates. EOS is published weekly on Tuesday. Ads must be received in writing on Monday 1 week prior to the date of the issue required.

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POSITIONS AVAILABLE

National Science Foundation, Division of Ocean Sciences: Chemical Oceanographer. The National Science Foundation, Division of Ocean Sciences is seeking qualified applicants for the position of Program Director for marine chemistry. This position will be filled on a rotational basis (2 year assignment) at the EC-14/15 level, (equivalent to GS-14/15), $37,671 to $50,112.50 per annum, depending on qualifications and experience.

The Program provides support for scientists primarily from academic institutions to pursue fundamental research in marine chemistry and chemical oceanography.

The selected candidate will carry out program planning, proposal evaluation, administration of research grants, and liaison with other federal agencies.

Applicants should have a Ph.D. in chemical oceanography or in a related chemical science field or the equivalent in experience, plus at least 3 years of specialized experience in chemical oceanography. Field experience in an academic institutional program is highly desirable.

Those interested in being considered for the position should send letters of interest and SF-171 or current resume by August 31, 1981 to the Division of Personnel and Management, Personnel Administration Branch, National Science Foundation, 1800 G St., NW, Washington, D.C. For further information call E. Paul Broglio—(202) 357-7840.

An equal opportunity employer.

University of Hawaii/Faculty Positions. The Department of Geology and Geophysics and the Hawaii Institute of Geophysics have openings for the 1981–1982 academic year. Rank is open dependent on qualifications. We are seeking persons who will participate in our teaching and research program in any of the following areas: (1) structural geology and marine tectonics; (2) hydrology and engineering geology; (3) marine seismology, magnetics, and gravity. To apply send a letter of interest, a current vita and 3 letters of reference to Dr. S. O. Schlanger, Chairman, Department of Geology and Geophysics, University of Hawaii, 2525 Correa Road, Honolulu, Hawaii 96822 (808-948-7826), or Dr. C. E. Helsley, Director, Hawaii Institute of Geophysics, same address (808-948-8760). Open until filled.

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Assistant Professor/Department of Geology, University of Vermont. The Geology Department at the University of Vermont is recruiting for a tenure track position at the assistant professor level to begin September 1982. Field of specialization should complement existing faculty expertise in petrology, structure and regional geology. Applications are solicited in, but not restricted to, geophysics, igneous petrology/geochronology, hydrology/Pleistocene or economic geology. The successful candidate will be expected to develop a research program involving both graduate students (M.S.) and advanced undergraduates. Applications will be accepted until December 1981.

Candidates should send resume and arrange for three letters of reference to be sent to:

Dr. John C. Drake
Acting Chairman
Department of Geology
University of Vermont
Burlington, VT 05405

The University of Vermont is an equal opportunity/affirmative action employer.

Adjunct Professor of Geophysics. Applications are invited for an adjunct associate professor (research) position. Applicants should be interested and currently involved in the relations between marine geophysics and active continental tectonics. Applicant should have a Ph.D. in geophysics with broad experience in the collection of marine geophysical data and its interpretation, familiarity with geology, particularly along active margins and experience in combining diverse marine and land data into large scale tectonic models. The appointee is expected to lead a vigorous research program. The adjunct position is non-tenure track. Salary range: $28,000–$31,000, equivalent to regular faculty positions with similar experience. Applicants should submit an application letter and resume to Mr. James Peters, California Employment Development Department, 297 West Hedding, San Jose, CA 95110, by September 30, 1981.

This advertisement was paid for by the employer.

Acoustical Physicist. Physics and Chemistry Department of Naval Postgraduate School (NPS), in Monterey, California, seeks applicants for tenure-track position at assistant or associate professor level, physicist who has experience and interest in teaching and research in area of acoustics. Primary mission of NPS is advanced education of Naval Officers. Department offers M.S. and Ph.D. degrees in Physics and Engineering Acoustics with major emphasis on Master's degree program. Most acoustics teaching is at senior and graduate level with concentration in underwater acoustics. Candidate must have Ph.D., be effective teacher and be interested in and capable of engaging in research. Current acoustics research areas: ocean acoustics including propagation, ambient noise, scattering and diffraction; propagation in tapered wave-guides; acoustic imaging; signal processing and non-linear acoustics. Send resume and references to Prof. O. B. Wilson, Department of Physics and Chemistry, Naval Postgraduate School, Monterey, CA 93940.

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Director, School of Geophysical Sciences. Applications and nominations are solicited for the position of Director of the School of Geophysical Sciences at the Georgia Institute of Technology. The department, with 21 academic and research faculty, 12 research and post-doctoral scientists, and 70 graduate students, conducts an extensive program of research and instruction, mainly at the graduate level leading to the MS and PhD degrees. Currently, research is conducted in the fields of dynamical and physical meteorology, atmospheric chemistry, solid earth geophysics, and geochemistry. Applicants must have an excellent academic reputation in research and teaching, with some administrative experience, and must qualify for the rank of professor. The position is now open; curriculum vitae and names of references should be sent to: Dr. L. A. Karlovitz, Chairman, Search Committee, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. Telephone: (404) 894-2700.

Georgia Tech, a unit of the University System of Georgia, is an equal education and employment opportunity institution.

Postdoctoral Positions. Scripps Institution of Oceanography invites applications for three to five postdoctoral positions distributed among the following fields:

1. Inshore processes:coastal engineering.
2. Marine pollution and the assimilative capacity of the ocean for social wastes utilizing resonance ionization spectroscopic analytical methods.
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Private foundation funding limits awards to U S citizens. Appointments are for one or two years Applicant should have a background in appropriate physical sciences for work in one of these fields at the Ph.D. level, or equivalent. Appointments in the University of California system will be at the level of Postgraduate Research or Assistant Research, salary from $17,112–26,400, commensurate with qualifications. Submit resume (specify position/field) including names of references, before *Sept 18, 1981* to: J. D. Frautschy, Deputy Director, A-010, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093. Request position profiles at the same address.

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Position in Reflection Seismology/Rice University, Houston, Texas. The Department of Geology plans to expand its geophysical program. Emphasis will be on reflection seismology. At this time applications are for the first of two open faculty positions. The successful applicant will help in the search for and selection of the second faculty member.

Your main responsibility will be to lead our department into the area of modern reflection seismology. Your main teaching and research interests should be in the acquisition and processing of reflection seismic data. You should also help in developing rigorous undergraduate and graduate curricula, which are supported by the traditional strength of the Math Sciences, Physics, and Electrical Engineering Departments at Rice. Enthusiasm to work with and undertake some joint projects with our geologists is essential.

Our plans are to acquire a computer system configured for high quality data processing. Substantial seed money for this facility is already in hand. Creative cooperation with the oil and geophysical industry in Houston, including a reasonable amount of consulting, is encouraged. Salary will be commensurate with qualifications and experience. Please send your curriculum vitae, a summary of experience in seismic processing, a statement of research interests, and names of three or more references to Dr. A. W. Bally, Chairman, Department of Geology, Rice University, P.O. Box 1892, Houston, Texas 77001. Application deadline—October 1, 1981.

Rice is an equal opportunity employer.

Atmospheric Scientist/Group Head. Senior staff scientist position available immediately at the NAIC's Arecibo Observatory. The successful applicant will be appointed as Head of the Atmospheric Sciences Group and will be expected to lead that group and to perform independent research using the Arecibo facilities. A Ph.D. degree in atmospheric or physical sciences or radar engineering and a record of solid research accomplishments are required. Experience with radar studies of the stratosphere, mesosphere, and ionosphere or with HF modifications of the ionosphere is desirable. Salary open. Please send resume and names of at least three references to Dr. Harold D. Craft, Jr., Acting Director, NAIC Observatory, Space Sciences Building, Cornell University, Ithaca, New York 14853. Cornell University are EOE/AAE.

NAIC/Cornell University are EOE/AAE.

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Special Sessions:

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- Mantle structure and dynamics
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- Rock-water interactions: Hydrothermal processes and metallogenesis

AGU

The Sixth Presentation of the
Maurice Ewing Medal
by the American Geophysical Union and the United States Navy
to
Manik Talwani
for leadership in marine geophysics

Citation

Manik Talwani's impact on the geosciences clearly places him among those who deserve to be honored as a Ewing medalist. He has contributed major advances to our understanding of Earth's fundamental characteristics and has provided direction that will help guide geological/geophysical research long into the future.

Born in Patiala, India, in 1933, Manik earned bachelor's and master's degrees at Delhi University. In the mid-1950's he moved to the United States and enrolled in Columbia University for his Ph.D. studies. It was the beginning of a long association between Manik and Columbia. When he earned his Ph.D. in 1959, it was already apparent that he was destined to make a significant impact on the geosciences. He has been the recipient of several important awards for his contributions and leadership. These include the first Krishnan Medal in 1965, from his home country, and the Macelwane Award from the American Geophysical Union, in 1967, for his pioneering achievements in the application of marine gravimetry to studies of Earth's crust and upper mantle. Since 1970, Manik has been a professor of geology at Columbia, and for 8 years he served as director of Lamont-Doherty Geological Observatory. This evening, for his continued contributions and leadership, Manik is being awarded the Maurice Ewing Medal. He is truly qualified for this distinction, based on his many important original contributions to marine geophysics, ocean technology and instrumentation, and also for his outstanding service to marine science.

Manik's approach to science can probably be best characterized with the word 'completeness.' He first identifies the problem (always major ones), then designs critical and ingenious experiments through which to attack the problem, and finally, subjects the data to thorough analysis specifically tailored to the particular problem. The vehicle for attack has generally been the oceanographic expedition. The innovative technology and computational methods he has developed have become the orthodox methods, and the scientific results he has obtained have become milestones in the study of Earth.

From 1959 to the early 1960's, Manik, along with J. Lamar Worzel and Maurice Ewing, developed computational schemes for gravity and magnetics and the methods to minimize errors in marine surface ship gravimetry; these remain the foundation of marine gravity and magnetic methods to this day. Since then there is virtually no marine geoscientist who has not, directly or indirectly, benefited from these accomplishments. Seeing the value of precise navigation, Manik also contributed significantly to the development of the satellite navigation system, which has obviously benefited us all. During the 1960's and following years, Manik, with his colleagues, applied these techniques to the investigation of many important geophysical problems. To name a few, they include his investigations of the Mid-Atlantic Ridge and the East Pacific Rise, the Puerto Rico and Tonga trenches, western North America, and the Caribbean region. All of these studies contributed basic information for the then-emerging new ideas of seafloor spreading and plate tectonics. Indeed, we owe Manik for so many discoveries: the existence of the low-density upper mantle, the nature of the magnetized crust under midoceanic ridges, the nature of the bulge in the oceanic plate before its subduction, and the detailed structures of numerous passive margins. The detailed analysis of the spreading history in the North Atlantic, carried out with Walter Pitman, is another classic contribution.

More recently, Manik's insight and scientific drive have led him to the development of large, towed seismic arrays for the future study of not only the sediments but also of the underlying crust and mantle. His vision has also sometimes pointed 'upwards.' For example, he played a leading role in the moon gravimetry program of the Apollo 17 mission. He has also been actively engaged in the analysis of satelliteborne radar altimetry. However, Manik now appears to be directing his vision 'vertically downward' into the great depths of Earth. We can expect he will soon be showing us new details of Earth's deep structure and processes. He is truly an insatiable explorer.

In addition to his many scientific feats, Manik has also contributed greatly to the promotion of ocean sciences. He has played a fundamental role in the development and guidance of the Deep Sea Drilling Project. His contribution in this regard, for which Manik probably deserves our highest appreciation, is his leadership as the director of Lamont-Doherty Geological Observatory. Under his leadership, significant investigations, too numerous to list, have been produced by scientists working at that institution, including many visiting researchers from all over the world. As one of the several Japanese scientists who have been privileged to spend some time at Lamont-Doherty, I would like to express my personal gratitude to Manik on this occasion. It was really our great pleasure to work in such a stimulating environment and to become acquainted with Manik and his beautiful family.

It is most appropriate indeed that Manik Talwani, who may be considered a stepfather of Lamont-Doherty Geological Observatory and who has maintained a position of excellence for that institution for so many years, is awarded a medal bearing the name of its paternal father. In 1967, in his response to the citation prepared by Maurice Ewing and Earl Dressler for the Macelwane Award, Manik said 'nothing could give me any greater encouragement.' His subsequent activities amply prove his remark. Today, through this award of the American Geophysical Union, Doc Ewing has once again provided encouragement to Manik Talwani for many years to come, and we can rest assured that Manik will continue to lead us in our scientific endeavors.

Seiya Uyeda

Acceptance

Thank you Seiya.

Mr. President, ladies and gentlemen: Doc Ewing has indeed provided encouragement to me—sometimes in most unusual ways. But, if he were here today, I am sure he would not mind my telling you a few things he did not teach me—not directly, anyway.

The first semester I was at Lamont as a student he was supposed to give a course in seismology. As it turned out, he spent almost the entire semester at sea, undoubtedly making many important discoveries. So, we did not learn much seismology. When he came back he made up for it by giving all of us A's for the course.

The next semester he was supposed to teach us gravity. This time he sent *me* away on a trip—actually it was to measure gravity in the Bahamas. I learned how to read a gravity meter and to operate a winch but not much else. I got an A in that course too.

The following summer he asked me to go to sea with him on VEMA. This time he taught me how *not* to shoot explosives. Because I had earned an A in my seismology course, I was made in charge of an ocean bottom seismograph. This seismograph looked something like a lawn mower, and it worked on the bottom of the sea. There was a rather complicated electrical switch within the seismograph. This switch had to be carefully set in the 'off' position. The instrument was then lowered to the bottom of the sea, but it was still connected to the ship by electric wires, and at this point somebody had to connect sticks of dynamite to the electrical wires. The catch was that if that switch in the seismograph, now lying on the bottom of the ocean, was not set properly, the dynamite would go off as soon as the connection was made. I figured that Doc should take the risk of making the connection. After all, he was the famous professor, the world's leading geophysicist, etc., etc.; I was just a student. Doc looked me in the eye and asked me if I was sure the switch was off. I said, 'Doc, I am reasonably sure.' 'Well,' he said, 'if you are reasonably sure, why don't you make the connection,' and he proceeded to stand back at a safe distance. Well, I didn't have much choice. I made the connection; the dynamite did not go off in my hands. But, from then on, when dealing with explosives, I made absolutely sure, not just reasonably sure. It was a good lesson.

On many occasions Ewing expressed the hope that his students would follow in his footsteps. While this was an admirable goal, his paths led at times to dangerous situations and his visions to precipitous heights. A scientist faces three kinds of obstacles. Scientific obstacles, and Doc invariably found his way around them; natural obstacles—wind, weather, rough seas, etc., and with the help of the good ship VEMA and its captain, Henry Kohler, Doc overcame these also; then there are political obstacles, and Ewing was just no good at negotiating those. Ten years ago, at the height of his career, Doc felt forced to leave the institution that he had spent virtually his entire lifetime in building. I doubt, though, that Doc intended his students to follow in his footsteps quite that far.

Mr. President, by giving me this award, you have also given recognition to my coworkers and students, because, surely, the award reflects our joint work, not just mine. I would also like to express my great appreciation to the U.S. Office of Naval Research, which through the years has provided magnificent and understanding support to basic research. Many important experiments and collections of data, which we now take for granted, would never have happened but for the foresight of the Office of Naval Research.

Mr. President, I am deeply touched by the honor you have done me, and I can honestly say that I was never more proud to be a fellow of the American Geophysical Union.

Manik Talwani

Meetings

River Diversion and Dams

The Brazilian National Committee on Large Dams is organizing the International Symposium on Layout of Dams in Narrow Gorges. The meeting, scheduled for April 26–27, 1982, in Rio de Janeiro, will discuss recent developments on the design criteria and construction methods of dams where narrow site dimensions require an innovative or unusual layout. Included will be hydrologic criteria for river diversion.

Deadline for submission of papers is December 15. For additional information, contact Flavio Miquez de Mello, Organizing Committee, Brazilian National Committee on Large Dams, Rua Real Grandeza, 219, 2281, Rio de Janeiro, Brazil.

National Radio Science Meeting

The second announcement and call for papers has been issued for the National Radio Science Meeting, slated for January 13–15, 1982, at the University of Colorado at Boulder.

The meeting is sponsored by the U.S. National Committee for the International Union of Radio Science, in cooperation with 10 IEEE groups and societies.

To receive the list of special paper topics solicited for the meeting and to receive directions on the preparation of abstracts, write to the U.S. National Committee for URSI, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418. Deadline for abstracts is October 1.

Call for Papers

Special Sessions

*Additional special sessions

Geodesy. Results from Satellite Altimeters; The Gravity Field: Techniques, Instruments and Results

Geomagnetism and Paleomagnetism. Magnetite Biomineralization by Living Organisms

Hydrology. Impact of Richards' Equation: A Semicentennial Session; Symposium on Geophysics and Groundwater—Methods, Applications, Problems; Erosion—Sedimentation Processes in Mountainous Terrain; Groundwater Contamination: Product of a Technological Society; Characterization of Variability and Uncertainty in Water Quality

Meteorology. Thunderstorm Dynamics Electrification and Recent Results from TRIP; The Use of Finite Elements in Meteorology and Oceanography; The Tropospheric-Stratospheric Exchange of Water Vapor over Panama: The NASA Experiment, August–September 1980*

Oceanography. Marginal Ice Zone Processes; HEBBLE (High-Energy Benthic Boundary Layer Experiment); West Coast Shelf Circulation; Vema Channel: Hydrography, Geochemistry and Sediment Dynamics; Hawaii-Tahiti Shuttle Experiment; Mid-Latitude Large-Scale Variability; Dynamics of Coastal Circulation over Topographic Features; Coastal Oceanography; Paleoceanography; Estuarine Processes: Physical, Chemical and Biological; SANDS (Shelf and Nearshore Dynamics of Sedimentation)*; Southern Ocean Studies*; MANOP—Manganese Nodule Project*

Planetology. Microwave Observations of the Planets; Volcanic Processes in the Solar System

Seismology. Multichannel Seismology; Observed Data from the Hazer Explosive

SPR-Cosmic Rays and Solar and Interplanetary Physics. Solar-Terrestrial Theory Program, Part II (Cosponsored by SPR-Magnetospheric Physics and SPR-Space Aeronomy)

SPR-Magnetospheric Physics. Aurora and Substorms (POSTER SESSION); Plasma Waves and Instabilities in Space (POSTER SESSION); Laboratory and Space Experiments; Solar-Terrestrial Theory Program Part I (Cosponsor: SPR-Cosmic Rays and SPR-Solar and Interplanetary Physics); Magnetospheres of Jupiter and Saturn

Tectonophysics. Rheology of the Lithosphere; Sedimentary Basins

Volcanology, Geochemistry, and Petrology. Geology of Loihi Seamount; Chemical and Convective Stratification of the Mantle; Petrogenesis of Igneous Rock and Intraoceanic Volcanic Areas; Volcanic Processes in the Solar System; Explosive Volcanism: Inception, Evolution, and Hazards*

Session Highlights

Meteorology

The Tropospheric-Stratospheric Exchange of Water Vapor Over Panama: The NASA Experiment, August–September 1980. The NASA Ames U-2 aircraft, 10 airborne experiments, and a team of NASA, NOAA, and university atmospheric scientists deployed to Panama in August–September 1980 to perform detailed studies of the role played by large cumulonimbus clouds in transporting water vapor into the stratosphere. Beside helping to explain why the stratosphere is so unexpectedly dry, the studies will also contribute to our understanding of how atmospheric pollutants move into stratospheric regions. For further information contact W. A. Page, Chief, Atmospheric Experiments Branch, NASA Ames, Moffett Field, CA 94035 (telephone: 415/965-5404).

Planetology

Microwave Observations of the Planets. Studies of the planets, using active and passive radio techniques, have greatly increased our knowledge of their environs (including atmospheres), surfaces, and dynamics. These advances have been achieved by using both spacecraft systems and Earth-based facilities. Abstracts summarizing current work or reviewing various aspects of the field are invited. For further information contact Thomas W. Thompson, Planetary Science Institute, 283 S. Lake Ave., Suite 218, Pasadena, CA 91101 (telephone: 213/449-4955).

Tectonophysics

Sedimentary Basins. As a result of their geologic and economic importance, sedimentary basins have been the subject of intensified study in recent years. This session will combine presentations of new data concerning basin structure and stratigraphy with results from theoretical models of basin evolution. The focus of discussion will be the roles of faulting, flexure, and thermal processes in determining basin geometry, subsidence, and marginal emergence. Session chairman: D. L. Turcotte, Department of Geological Sciences, Cornell University, Ithaca, New York 14853.

Rheology of the Lithosphere. Papers presented in this special session will bring together observations of the deformation of continental and oceanic lithosphere with theoretical and empirical laws describing the rheology of earth materials at lithospheric temperatures and pressures. Topics of discussion will include the validity of extrapolating laboratory data to geologic strain rates, the role of fluid as a weakening mechanism, the effect of chemical differences on rock strength, and the extent to which linear approximations to the stress/strain laws can describe the observations. Session chairman: John Rundle, Sandia Laboratories, Albuquerque, New Mexico 87115.

Volcanology, Geochemistry, and Petrology

Geology of Loihi Seamount. Loihi seamount lies 30 km southeast of the island of Hawaii. Recent studies show it to be seismically active and covered with young glossy pillow lavas. Its location, and evidence for recent volcanic activity, indicate that Loihi seamount is the youngest volcano in the Hawaiian-Emperor volcanic chain. Due to the small size and the youth of the volcano it is possible, for the first time, to examine the early submarine-shield-building phase of Hawaiian volcanism. This session will consist of invited and contributed papers on the results of recent geophysical bathymetric, photographic, and petrologic studies of the dredged lavas. The session organizers are David Clague, U.S. Geological Survery (MS 99), 345 Middlefield Road, Menlo Park, CA 94025 (telephone: 415/856-7133) and Alex Malahoff, NOS, NOAA, Rockville, Md 20852 (telephone: 301/443-8720).

Chemical and Convective Stratification of the Mantle. It is the consensus among earth scientists that plate tectonics is the surface manifestation of convective processes in the mantle, but there is little agreement on the vertical scale lengths characterizing the material flow involved in plate motions. Currently receiving much attention is the hypothesis that mantle convection is stratified into two or more shells of different compositions, separated by thermal and perhaps mechanical boundary layers. This special session will focus on the geophysical and geochemical evidence for and against this hypothesis. The session organizer is Thomas H. Jordan, A-015, Scripps Institute of Oceanography, La Jolla, CA 92093 (telephone: 714/452-2809).

Petrogenesis of Igneous Rocks in Intra-Oceanic Volcanic Arcs. Intra-oceanic volcanic arcs are built on oceanic crust and are associated with subduction zones. As such, magma contamination by continental crustal rocks is absent, and the igneous rocks are thought to be products of magma generation in the mantle and/or crust with geochemical and physical effects contributed from the subducted slab. Some specific petrologic problems of igneous rocks in intra-oceanic volcanic arcs include (1) the sources of magmas, (2) the chemical and physical effects of the subducted slab on the geochemical characteristics of the magmas, (3) the relative proportions of erupted rock types, (4) the episodicity of volcanism, (5) the possible geochemical maturing, (6) the time and space relationships of volcanic and plutonic rocks, and (7) the association of arc volcanism and metallogeny. This session will be organized to focus on one or more of these specific petrologic problems. The session organizers are Tracy L. Vallier, U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025 (telephone: 415/856-7048) and Robert W. Kay, Department of Geological Science, Kimball Hall, Cornell University, Ithica, NY 14853 (telephone: 607/256-3461).

Explosive Volcanism: Inception, Evolution, and Hazards. The volcanic process will be considered broadly from the viewpoints of magma generation, migration, emission, and the consequences of explosive eruption. Magma genesis will be examined both in evidence from upper mantle xenoliths and isotope ratios for volcanic rocks. Possible circumstances of magma generation will be evaluated for both compressional and extensional tectonic environments. Some aspects of social and environmental crises caused by explosive volcanism will be discussed. This symposium, organized in cooperation with the National Research Council, will have sessions of both invited and contributed papers and will emphasize volcanic relations in the western United States. The session is being organized by F. R. Boyd, Geophysical Laboratory, Carnegie Institute of Washington, 2801 Upton Street, N.W., Washington, D.C. 20008 (telephone: 202/966-0334).

Planetology/Volcanology, Geochemistry and Petrology

Volcanic Processes in Solar System. This session will examine the range of volcanic activity on different planetary bodies within the solar system. Included will be discussions of sulfur volcanism on Io, generation of basaltic magma on the moon, the volcanic history of Mars, and the role of plate tectonics in controlling styles of terrestrial volcanism. Emphasis will be placed on volcanic processes and comparisons between mechanisms operating on Earth and those on other planets. The session is coorganized by the Planetology and VGP sections and will include both invited and contributed papers. The organizer is Michael H. Carr, U.S. Geological Survey, Menlo Park, CA (telephone: 415/323-8111, ext. 2361).

Program Committee

Meeting Chairman. Martin Walt, Lockheed Missiles and Space Company
Geodesy (G). Bob E. Schutz, University of Texas at Austin
Geomagnetism and Paleomagnetism (GP). Maureen B. Steiner, University of Wyoming; Jack Hillhouse, USGS
Hydrology (H). Edward D. Andrews, USGS
Meteorology (M). Ronald C. Taylor, National Science Foundation
Oceanography (O). Barbara Hickey, University of Washington
Planetology (P). Richard Simpson, Stanford University; James B. Pollack, NASA Ames
Seismology (S). Robert J. Geller, Stanford University
SPR-Aeronomy (SA). Thomas A. Potemra, The Johns Hopkins University
SPR-Cosmic Rays and SPR-Solar and Interplanetary Physics (SS/SC). George Gloeckler, University of Maryland
SPR-Magnetospheric Physics (SM). Michael Schulz, Aerospace Corporation
Tectonophysics (T). Marcia McNutt, USGS
Volcanology, Geochemistry and Petrology (V). G. Brent Dalymple, USGS

General Regulations

Abstracts may be rejected without consideration of their content if they are not received by the deadline or are not in the proper format. Abstracts may also be rejected if they contain material outside the scope of AGU activities or because they contain material already published or presented elsewhere. ONLY ONE CONTRIBUTED PAPER BY THE SAME FIRST AUTHOR WILL BE CONSIDERED for presentation; additional papers (unless invited) will be automatically rejected.

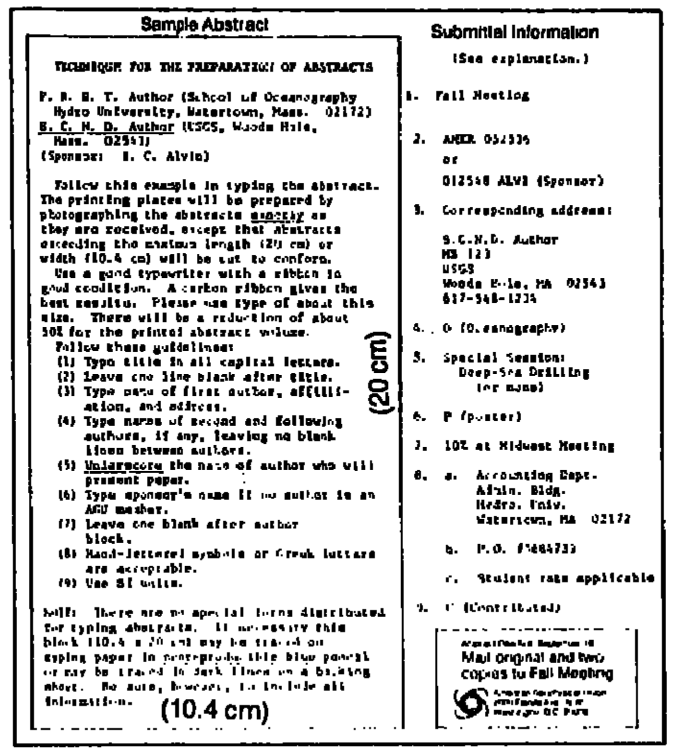
Only AGU members may submit an abstract. The abstract of a nonmember must be accompanied by a membership application form (with payment), or it must be sponsored by an AGU member.

There is a publication charge of $40.00 for each abstract ($20.00 if the first author is a student member.) Both invited and contributed papers are subject to the publication charge. The abstract must be received at AGU by September 16 to avoid an additional $25.00 charge.

AGU will acknowledge receipt of an abstract by returning a copy of it to the corresponding author. Notification of acceptance and scheduling information will be mailed in late October.

Ten minutes is normally allowed for the presentation of each contributed paper, and only 2" × 2" (35-mm) slide projectors and viewgraphs are usually available as standard equipment at the meeting. All other equipment is available at cost, plus a $10.00 billing charge if we have to invoice.

Instructions for Preparing Meeting Abstracts



For actual size, see *Eos*, vol. 62, no. 26, p. 566.

The abstract page is divided into two parts: the abstract itself and the submittal information. Follow the instructions for both carefully. Please use a carbon ribbon to type the material, and do not exceed the maximum dimensions of the abstract of 10.4 cm by 20 cm. Abstracts that exceed the noted size limitations will be trimmed to conform to the proper dimensions.

The meeting program will be prepared by photographing the abstracts exactly as they are received. Use the model abstract to prepare the final version. Submission of an abstract for an AGU meeting is presumed to carry with it permission for AGU to reproduce the abstract in all editions of *Eos* and in the programs and reports relating to the meeting. It is also presumed to permit the free copying of those papers. Although *Eos* is a copyrighted journal, authors are not requested to transfer copyright; copyright, where it exists, will be reserved by the authors.

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3. Corresponding address.—Give complete address and phone number of author to whom all correspondence (acknowledgment and acceptance letters) should be sent. Abbreviate as much as possible.

4. Section of AGU to which abstract is submitted.—Use letter abbreviations of one of the following: G (Geodesy), GP (Geomagnetism and Paleomagnetism), H (Hydrology), M (Meteorology), O (Oceanography), P (Planetology), S (Seismology), SA (Aeronomy), SM (Magnetospheric Physics), SC (Cosmic Rays), SS (Solar and Interplanetary Physics), T (Tectonophysics), VGP (Volcanology, Geochemistry, and Petrology), U (Union).

5. Type title of special session (if any) to which submittal is made.

6. Indicate your preference for a particular kind of presentation by one of the following letters: O for oral, P for poster. The chairman may assign your paper to either of these types of presentation in order to fit his program plan.

7. Percent of material previously presented or published, and where.

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